5 WATER QUALITY

5.1 INTRODUCTION

5.1.1 This Section deals with the assessment of the impacts on water quality of the construction and operation of the International Theme Park and Its Essential Associated Infrastructure.

5.1.2 The construction phase assessment has considered the following aspects.

- the potential impacts to marine water quality from the construction of the reclamations at Penny's Bay and at Yam O, including cumulative impacts with other concurrent projects; and
- the potential impacts to marine water quality from land based construction works for the Theme Park and the associated infrastructure, including road and rail links and the artificial lake.

5.1.3 The operation phase assessment has considered the following aspects.

- the potential impacts to hydrodynamics from the Theme Park reclamations and to marine water quality from sewage effluent and stormwater discharges from the Theme Park and surrounding areas;
- the protection of water quality in the artificial lake so that its beneficial uses as a recreation area for water sports, as a source of irrigation water for the Theme Park and as an area of general amenity value may be maintained;
- the adequacy of the sewerage system and of the Siu Ho Wan Sewage Treatment Works so that adverse impacts to water quality due to the discharge of untreated sewage effluent to marine waters may be prevented; and
- the potential impacts to marine water quality from the operation of the road and rail links for the Theme Park.

5.1.4 The overall aim of the above assessment work was to determine the acceptability of any predicted impacts to water quality from the construction and operation of the Theme Park and its Associated Essential Infrastructure. Predicted impacts have been assessed with reference to the relevant environmental legislation and standards, and suitable measures devised to mitigate any potential adverse impacts. The need for construction and operation Environmental Monitoring and Audit has been assessed and recommendation made where necessary.

5.2 RELEVANT LEGISLATION AND GUIDELINES

5.2.1 The following relevant pieces of legislation and associated guidance are applicable to the evaluation of water quality impacts associated with the *Construction of an International Theme Park in Penny's Bay and its Essential Associated Infrastructure*.

- *Water Pollution Control Ordinance (WPCO);*
- Technical Memorandum for Effluents Discharged into Drainage and Sewerage Systems Inland and Coastal Waters; and
- *Environmental Impact Assessment Ordinance (Cap. 499. S.16*), Technical Memorandum on Environmental Impact Assessment Process (EIAO TM), Annexes 6 and 14.

5.2.2 Apart from the above statutory requirements, the Practice Note for Professional Persons, *Construction Site Drainage* (ProPECC PN 1/94), issued by ProPECC in 1994, also provides useful guidelines on the management of construction site drainage and prevention of water pollution associated with construction activities.

5.2.3 The Drainage Services Department (DSD) *Sewerage Manual* provides design standards for sewerage systems and is used in the assessment of the adequacy of the sewerage system serving the Theme Park and associated developments.

Water Pollution Control Ordinance

5.2.4 The *Water Pollution Control Ordinance* (*WPCO*) is the legislation for the control of water pollution and water quality in Hong Kong. Under the *WPCO*, Hong Kong waters are divided into 10 Water Control Zones (WCZs). Each WCZ has a designated set of statutory Water Quality Objectives (WQOs). The WQOs set limits for different parameters that should be achieved in order to maintain the water quality within the WCZs. The Theme Park will be located within the Southern WCZ, and discharges from the construction and operation of the Theme Park and associated developments will also fall within the Western Buffer and North Western WCZs. The locations of the WCZs are shown on *Figure 5.2a*.

5.2.5 The WQOs for the Western Buffer, the Southern and the North Western WCZs, which are presented in *Tables D1a, D1b* and *D1c* respectively, are applicable as evaluation criteria for assessing compliance of any effects from the construction and operation of the Theme Park and associated developments.

Technical Memorandum for Effluent Discharges

5.2.6 All discharges during both the construction the operational phases of the Project are required to comply with the *Technical Memorandum for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters* (TM) issued under Section 21 of the *WPCO*. The TM defines discharge limits to different types of receiving waters. Under the TM, effluents discharged into the drainage and sewerage systems, inshore and coastal waters of the WCZs are subject to pollutant concentration standards for particular discharge volumes. Any new discharges within a WCZ are subject to licence conditions and the TM acts as a guideline for setting discharge standards for the licence.

EIAO TM

5.2.7 *Annexes 6* and *14* of the EIAO TM provide general guidelines and criteria to be used in assessing water quality issues.

5.3 EXISTING ENVIRONMENT/SENSITIVE RECEIVERS

5.3.1 The majority of the Theme Park development and associated infrastructure will be constructed on a reclamation at Penny’s Bay, on the south eastern side of the northern tip of Lantau Island. A small reclamation for the construction of Road P2 on the opposite shoreline of Lantau Island in Yam O Wan is also proposed. The sewage effluent from the Theme Park and its associated developments will be conveyed to the Siu Ho Wan Sewage Treatment Works for treatment and discharge via a submarine outfall.

Hydrodynamic Conditions

5.3.2 Kap Shui Mun, which is the channel between the northern tip of Lantau Island and Ma Wan Island, forms one of the main flow channel between the waters of the North West New Territories and the Western Harbour. The other flow channel is on the northern side of Ma Wan Island, the Ma Wan Channel. Tidal current speeds through Kap Shui Mun are generally high, greater than 1 m s^{-1} for the ebb phase of the tidal cycle for spring tides. In the vicinity of the reclamation at Yam O Wan, tidal currents are lower due to the sheltering effect of the headlands to north east and south west. Further offshore, currents are stronger, up to 0.6 m s^{-1}, with the main flows from the Pearl Estuary converging in this area before bifurcating around Ma Wan Island.

5.3.3 On the Penny's Bay side tidal currents are much lower, less than 0.3 m s^{-1}. This is because the main flows to and from Kap Shui Mun are along the East and West Lamma Channels.

5.3.4 The areas potentially affected by the Project will exhibit seasonal differences in terms of salinity and temperature stratification. To the west of Ma Wan in the wet season strong salinity and temperature stratification is to be found due to the outflow from the Pearl Estuary. To the east of Ma Wan the stratification will be less strong due to the turbulence in the Ma Wan Channel and Kap Shui Mun causing a partial degradation in the stratification. In the sheltered bay along the southern Lantau Island coastline, stratification may be present due to localised run-off and heating of the relatively stagnant surface waters.

Water Quality Conditions

5.3.5 The Project area is within three WCZ's: the Southern WCZ, the Western Buffer and North Western WCZs. There are three routine EPD water quality monitoring stations (one for each WCZ) located in the vicinity of the Project area; the locations of these stations are shown in *Figure 5.2a.* A summary of water quality data for each of the stations is presented in *Table 5.3a*. These data were measured in 1998 (most recently published data[(1)]).

(1) EPD (1999). Marine Water Quality in Hong Kong in 1998.

Table 5.3a - EPD Routine Water Quality Monitoring Data in the Vicinity of the Project Area

WQ Parameter	WM4	SM10	NM1
Temperature (°C)	23.4 (16.7 - 27.7)	23.4 (16.3 - 27.2)	23.6 (18.2 - 26.8)
Salinity (ppt)	30.9 (25.9 - 33.6)	30.2 (26.9 - 33.4)	29.3 (21.9 - 32.5)
Dissolved Oxygen (mg L^{-1})	3.2 (2.9 - 8.1)	4.0 (3.2 - 7.2)	3.5 (3.2 - 8.4)
Dissolved Oxygen Bottom (mg L^{-1})	2.6 (2.2 - 8.1)	4.3 (3.9 - 7.2)	2.9 (2.7 - 8.3)
5-Day Biochemical Oxygen Demand (mg L^{-1})	0.7 (0.2 - 1.5)	0.9 (0.1 - 1.8)	0.9 (0.2 - 2.0)
Suspended Solids (mg L^{-1})	7.6 (1.2 - 17.4)	6.9 (4.1 - 9.9)	4.0 (1.1 - 6.7)
Total Inorganic Nitrogen (mg L^{-1})	0.29 (0.17 - 0.42)	0.27 (0.14 - 0.43)	0.43 (0.24 - 0.66)
Unionised Ammonia (mg L^{-1})	0.005 (0.002 - 0.007)	0.003 (0.001 - 0.009)	0.005 (0.002 - 0.007)
E.coli (cfu $100mL^{-1}$)	510 (42 - 1,900)	9 (2 - 300)	110 (6 - 570)

Notes:
1. Data presented are depth averaged, except as specified.
2. Data presented are annual arithmetic mean except for *E. coli* which are geometric means and dissolved oxygen which are 10^{th} percentile.
3. Data enclosed in brackets indicate the ranges.
4. Shaded cells indicate non-compliance with the WQOs.

5.3.6 The EPD monitoring report (2) states that there were non-compliances with the WQOs for depth averaged dissolved oxygen at all three stations, although compliance was achieved with the bottom dissolved oxygen WQO at the stations. This is a deterioration from data collected in 1997, which showed compliance with both the depth averaged and bottom dissolved oxygen WQO (3). A review of unpublished data for 1999 (4) determined that compliance with the depth averaged dissolved oxygen WQO was achieved. It may therefore be concluded that it is premature to assess that the dissolved oxygen concentrations in the study area are deteriorating based on the 1998 data alone.

5.3.7 The total inorganic nitrogen WQO is exceeded at Station SM10. The exceedance of the total inorganic nitrogen WQO at Station SM10 has been recorded for the last ten years. It is worth noting that the WQO for total inorganic nitrogen is not exceeded at Station WM4, even though the average concentration is higher than that at Station SM10. This is because of the different WQO for total inorganic nitrogen in the Western Buffer WCZ, which is higher compared with that of the Southern WCZ.

5.3.8 The WQO for *E. coli* at Station SM10, which is in a Secondary Contact Recreation Subzone, is achieved and the levels are low enough to satisfy the WQO for bathing beaches. Stations WM4 and NM1 are somewhat influenced by sewage effluent discharges, as shown by the higher *E. coli* concentrations. This is possibly because these stations are in one of the main

(2) EPD (1999). Op cit.
(3) EPD (1998). Marine Water Quality in Hong Kong in 1997.
(4) Data provided by EPD.

flow paths between the waters of the North West New Territories and Victoria Harbour and will therefore receive dilute discharges of sewage from these areas.

5.3.9 The data for temperature, salinity and dissolved oxygen show a wide variation, which indicates seasonal changes. These are most pronounced at Station NM1, which is the station most influenced by the discharges from the Pearl River estuary.

Identification of Sensitive Receivers

5.3.10 The construction and operation of the Theme Park and associated infrastructure will have the potential to directly affect water quality in the waters along the southern and northern sides of Lantau Island. The Penny's Bay reclamation and small Yam O reclamation may also change tidal current patterns around Ma Wan, which could in turn cause water quality effects in the East and West Lamma Channels, the Rambler Channel and in the western end of Victoria Harbour. Sensitive receivers have been identified in these potentially affected areas under the broad designations of gazetted and non-gazetted bathing beaches, water intakes, fish culture zones, sites of ecological value and recreational areas. The identified sensitive receivers in each of these categories are as follows:

- **Gazetted Bathing Beaches:** Butterfly, Castle Peak, Kadoorie, Cafeteria Old, Cafeteria New, Golden, Gemini, Hoi Mei Wan, Casam, Lido, Ting Kau, Approach, Tung Wan (Ma Wan), Silvermine Bay, Tung Wan (Cheung Chau), Kwun Yam Wan, Hung Shing Yeh and Lo So Shing;
- **Non-Gazetted Beaches:** Dragon and Discovery Bay;
- **Water Intakes:** Castle Peak Power Station cooling water intake, Chek Lap Kok cooling water intake, Tsuen Wan Water Supplies Department (WSD) intake, Tsing Yi WSD intake, Cheung Sha Wan WSD intake, Yau Ma Tei WSD intake, Sheung Wan WSD intake, Kennedy Town WSD intake, Queen Mary Hospital/Sha Wan Drive intake and Wah Fu Estate intake ;
- **Fish Culture Zones:** Ma Wan (South and North), Cheung Sha Wan, Lo Tik Wan and Sok Kwu Wan;
- **Sites of Ecological Interest**: Sha Chau, Tung Chung Bay, The Brothers, Yam O Wan, Kau Yi Chau, Green Island, Pak Kok, Shek Kok Tsui and Luk Chau; and
- **Recreational Uses:** Discovery Centre at Sze Pak Wan.

5.3.11 In addition to the identified sensitive receivers, there are a number of open water monitoring stations which have been considered in this study to assess water quality in the marine waters potentially affected by Project construction and operational activities. The locations of the above sensitive receivers and open water monitoring stations are shown in *Figure 5.3a*. It should be noted that the Anglers Beach, which is currently a gazetted bathing beach, is not included as a sensitive receiver. This is because the beach will be lost when the construction of the proposed Sham Tseng Further Reclamation commences in 2004.

5.3.12 The WQOs presented in *Annex D1* are considered to be suitable as assessment criteria at the identified sensitive receivers and monitoring stations. A number of the sensitive receivers are Water Supplies Department (WSD) sea water intakes. The WSD has a set of standards for the quality of abstracted water (see in *Table 5.3b*). Water quality at the WSD sea water intakes has been assessed against these standards, in addition to the WQOs.

Table 5.3b - WSD Water Quality Criteria for Abstracted Seawater

Parameter	Criterion
Colour (HU)	<20
Turbidity (NTU)	<10
Threshold Odour No.	<100
Ammoniacal Nitrogen (mg L^{-1})	<1
Suspended Solids (mg L^{-1})	<10
Dissolved Oxygen (mg L^{-1})	>2
5-day Biochemical Oxygen Demand (mg L^{-1})	<10
Synthetic Detergents (mg L^{-1})	<5
E. coli (cfu $100mL^{-1}$)	<20,000

5.4 ASSESSMENT METHODOLOGY - CONSTRUCTION

5.4.1 The assessment of impacts to water quality during the construction phase has been divided into two aspects, formation of the reclamation and land based construction activities, including those for the Theme Park and for the road and rail links.

RECLAMATION FORMATION

General Methodology

5.4.2 Impacts to water quality during the construction of a reclamation at Penny's Bay were assessed as part of the studies for Container Terminals 10 & 11 (5) (6). In these two studies, computer modelling of the dispersion of fine sediment in suspension from the dredging and filling works was carried out. The modelling predicted increases in suspended sediment concentrations in the marine waters adjacent to the works area and at sensitive receivers and to predicted increases in siltation on the sea bed. The results of the modelling were also analysed to determine the effects of predicted increased suspended sediment concentrations on dissolved oxygen and nutrient levels in the receiving waters. The computer modelling carried out for the *Design of Reclamation and Edge Structures for Container 10 and 11 and Back-up Areas* (7) was the most comprehensive and detailed of the two studies and has been used in the assessment of construction phase impacts for this EIA Study. The EIA report for this study was previously approved and is placed under *Section 15(1)(f)* of the *EIAO*. It is appropriate to make reference to the results of the computer modelling from this previous study because the modelling simulated the impacts to water quality from the construction of a reclamation at Penny's Bay, which is the concern for this Study. The main difference between this Study and the previous study is the programme for reclamation construction and it is for this reason that the assessment is being carried out for this Study, instead of simply quoting the conclusions from the previous study.

5.4.3 The construction programme for the Penny's Bay reclamation has been analysed to determine the maximum likely rates of loss of fine sediment to suspension during dredging and filling works. The maximum loss rates have then been compared with those presented in the *Design of Reclamation and Edge Structures for Container 10 and 11 and Back-up*

(5) Halcrow Asia Partnership Ltd (1994). Lantau Port Development - Stage 1. Container Terminals No. 10 & 11 Ancillary Works (Design). Environmental Impact Assessment. Final Report.

(6) Maunsell Consultants Asia Ltd (1995). Lantau Port Development Stage 1. Design of Reclamation and Edge Structures for Container Terminals 10 and 11 and Back-up Areas. Environmental Impact Assessment. Final Report.

(7) Maunsell Consultants Asia Ltd (1995). *Op cit.*

Areas. Increases in suspended sediment concentrations and deposition rates for this Project have been calculated on a pro-rata basis using the ratio of the loss rates for this Project and those in the previous study. Impacts to dissolved oxygen and nutrient concentrations have been estimated based on the sediment quality in the area of Penny's Bay to be dredged, the calculated increases in suspended sediment concentrations from this Project and the predicted impacts to these two water quality parameters from the previous study. The calculated increases in suspended sediment concentrations have then compared with the Water Quality Objectives to determine the acceptability of the predicted impacts. The calculated effects on dissolved oxygen and nutrient concentrations have been compared with background concentrations to determine compliance with the relevant Water Quality Objectives. The potential release of contaminants to the water column have been calculated based upon sediment quality data and suspended sediment concentrations. The potential for release has been assessed for metals of concern, PAHs, PCBs and TBT. The predicted deposition have been compared with threshold of impact criteria for ecological sensitive receivers to determine whether the impacts will be acceptable.

5.4.4 Along the northern shore of Lantau Island there will be a small 10 ha reclamation (see *Figure 2.3a*) constructed to provide land for the construction of part of Road P2 to the north of the new rail station. No previous predictive modelling of impacts associated with the construction of a reclamation in this area have been carried out. The rates of construction for this Yam O reclamation are likely to be much slower than those for the Penny's Bay reclamation for the Theme Park and the construction plant requirements considerably lower.

5.4.5 A near field model of sediment dispersion has therefore been used [(8)] to assess the impacts from suspended sediment plumes formed during the construction of this small Yam O reclamation. This is the same approach as was adopted for the assessment of near field sediment plumes during the study *Design of Reclamation and Edge Structures for Container 10 and 11 and Back-up Areas* [(9)]. In this model the depth averaged suspended sediment concentrations are calculated at varying distances from the source of the suspended sediments. This model has been used to predict suspended sediment concentrations with distance from the works and hence determine at what distance compliance with the Water Quality Objective will be achieved. The predicted suspended sediment concentrations in association with sediment quality data have also been used to calculate the effects of sediment plumes on dissolved oxygen concentrations, nutrients and the release of pollutants from the sediments, such as metals, PAHs, PCBs and TBT.

5.4.6 Concurrent projects which have the potential to result in cumulative impacts have been identified. The assessment of cumulative impacts from concurrent projects has been conducted by making use of computer modelling predictions of the transport of fine sediments in suspension from previous studies which simulated the impacts of these projects. The predicted locations of the suspended sediment plumes for each of the above identified projects which could occur concurrently with the construction of this Project have been examined to determine whether the plumes would overlap with those from the construction of the Penny's Bay and Yam O reclamations. Where plumes from any of the concurrent projects were found to overlap with those from the Penny's Bay and Yam O reclamation, cumulative impacts at sensitive receivers have been assessed by summing the

(8) R E Wilson. A Model for the Estimation of the Concentrations and Spatial Extent of Suspended Sediment Plumes. Estuarine and Marine Coastal Science (1979), Vol 9, pp 65-78.
(9) Maunsell Consultants Asia Ltd (1995). *Op cit*.

predicted elevations in suspended sediment concentrations at the sensitive receivers from each of the concurrent projects with those from the Penny's Bay and Yam O reclamations. The predicted elevations in suspended sediment concentrations have then been compared with the relevant Water Quality Objective.

Uncertainties in Assessment Methodology

5.4.7 Quantitative uncertainties in the assessment of the impacts from suspended sediment plumes should be considered when drawing conclusions from the assessment. In carrying out the assessment, realistic worst case assumptions have been made in order to provide a conservative assessment of environmental impacts including:

- The assessment is based on previous modelling results which input the sediment lost to suspension at the water surface to minimise local settling and, therefore, would predict higher concentrations remote from the works area;
- The assessment is based on the peak dredging and filling rates, which will only occur for short periods of time; and
- The calculations of loss rates of sediment to suspension are based on conservative estimates for the types of plant and methods of working.

LAND BASED CONSTRUCTION ACTIVITIES

5.4.8 The assessment of the potential impact of land based construction activities on water quality has been undertaken in a qualitative manner. Consideration has been given to controlling potentially harmful impacts from site works and to the use of 'best' practice measures to minimise the potential for discharges of pollutants to nearby receiving water courses in vicinity of the Project site and the coastal waters of Penny's Bay and Yam O Wan. The land based construction activities which have been considered include those for the Theme Park, the artificial lake and those for the road and rail links.

5.5 IDENTIFICATION OF ENVIRONMENTAL IMPACTS - CONSTRUCTION

5.5.1 The identification of potential water quality impacts during the construction phase has been divided into two aspects, formation of the reclamation and land based construction activities, including those for the Theme Park and for the road and rail links.

RECLAMATION FORMATION

Suspended Sediment

5.5.2 During dredging and filling for the construction of the reclamations, fine sediment will be suspended into the water column, which may then be transported away from the works area by tidal currents to form sediment plumes. The quantities of fine sediment lost to suspension during dredging and filling will primarily depend on dredging and filling rates and methods. Impacts from suspended sediment may be caused by sediment plumes being transported to sensitive areas, such as fish culture zones, bathing beaches, water intakes, areas of ecological value and recreational areas.

5.5.3 A review of the computer modelling of dispersion of fine sediment in suspension from the study *Design of Reclamation and Edge Structures for Container Terminals* (10) has been carried out to determine the extent of sediment plumes from dredging and filling activities at Penny's Bay. This review has determined that only a small number of the sensitive receivers identified in *Section 5.3.3* could potentially experience elevated suspended sediment concentrations. These sensitive receivers, the locations of which are shown in *Figure 5.3a*, are defined as follows

- Ma Wan Fish Culture Zone (North and South);
- Tung Wan Beach, Ma Wan;
- Sze Pak Wan;
- Discovery Bay Beach;
- Kau Yi Chau; and
- Silvermine Bay Beach.

5.5.4 The closest identified sensitive receiver to the reclamation at Yam O is the point marked as Yam O Wan. This point has been positioned to determine the operational water quality within the bay following completion of the Theme Park developments as concerns regarding potential stagnation of the bay have been identified. This location has not therefore been considered as a sensitive receiver for the assessment of Yam O reclamation construction impacts; the nearest other sensitive receiver is the Ma Wan Fish Culture Zone, which is already included above.

5.5.5 Suspended sediment plumes passing over a sensitive receiver will cause the ambient suspended sediment concentrations to be elevated; the level of elevation will determine whether the impact is adverse. The determination of the acceptability of elevations in suspended sediment concentrations has been based on the Water Quality Objectives. The WQO for suspended sediments for the Southern, Western Buffer and North Western WCZs is defined as being an allowable elevation of 30% above the background. The Environmental Protection Department (EPD) maintains a flexible approach to the definition of ambient levels, preferring to allow definition on a case-by-case basis rather than designating a specific statistical parameter as representing ambient. It was agreed in a previous study of the environmental impacts of released suspended sediments (11) that the ambient value may be represented by the 90th percentile of reported concentrations. EPD routine monitoring data has been used as the source of the reported concentrations, with the monitoring station nearest to each of the identified sensitive receivers being defined as representative of that location. EPD monitoring data and allowable elevations in suspended sediment concentrations are summarised in *Table 5.5a*.

Table 5.5a - Ambient and Tolerance Values for Suspended Sediment Concentrations (mg L^{-1}) in the Vicinity of Sensitive Receivers

Sensitive Receiver (Relevant EPD Monitoring Station)	Dry Season		Wet Season	
	90th Percentile	30% Tolerance	90th Percentile	30% Tolerance
Ma Wan Fish Culture Zone Tung Wan Beach, Ma Wan (WM4)	15.0	4.5	10.7	3.2

(10) Maunsell Consultants Asia Ltd (1995). *Op cit.*
(11) ERM (1997). Environmental Impact Assessment for the Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit. Final Report.

Sensitive Receiver	Dry Season		Wet Season	
Sze Pak Wan Discovery Bay Beach (SM10)	12.5	3.8	11.0	3.3
Kau Yi Chau (SM9)	12.6	3.8	35.2	10.6
Silvermine Bay Beach (SM11)	12.6	3.8	18.0	5.4

Notes :All values are depth averaged.

5.5.6 The allowable elevation in suspended sediment concentration as defined by the WQO for a particular site corresponds to the 30% tolerance level. The calculated maximum suspended sediment concentrations from the dredging and filling have been compared with the 30% tolerance values in the above table to determine the acceptability of the impacts.

5.5.7 At the Yam O reclamation site it will also be necessary to determine the distance from the dredging operation at which compliance with the WQO is achieved. The closest station to the works is NM1, where the 90^{th} percentile suspended sediment concentrations in the wet and dry seasons were 7.6 mg L^{-1} and 10.6 mg L^{-1} respectively. The allowable increases in suspended sediment concentrations are therefore 2.3 mg L^{-1} and 3.2 mg L^{-1} for the wet and dry seasons respectively. These allowable increases have then been compared to the calculated suspended sediment concentrations to determine the distance from the dredging operations at which compliance with the WQOs will be achieved.

Sediment Deposition

5.5.8 Impacts from the formation of suspended sediment plumes may also be related to the settling of sediment onto the seabed and smothering any organisms present. A deposition rate of 0.2 kg m^{-2} day^{-1} has been determined as a level of concern for corals. Further discussion of the selection of this value is contained in *Section 8.5* (marine ecological impact assessment). The calculated rates of deposition have been compared to this level of concern at those sensitive receivers at which it is applicable to determine whether the predicted impacts would be acceptable.

Water Quality

5.5.9 The loss of sediment to suspension during dredging and filling may have chemical effects on the receiving waters. This is because the sediment may contain organic and chemical pollutants. As part of this Project laboratory testing of sediment samples was undertaken. The results of the testing found that a small proportion of the sediment would be classed as contaminated (Class C) in both Penny's Bay and Yam O Bay, according to EPD's *Technical Circular No 1-1-92*, based on high levels of copper. Other parameters of concern have been identified as PAHs, PCBs and TBT. Further discussion of the sediment classification and methods of disposal of dredged sediments is contained in *Section 6*, which assesses waste management. The results of the sediment quality testing, which have relevance to the water quality assessment are summarised in *Table 5.5b*.

Table 5.5b - Summary of Sediment Quality Testing

Testing Parameter	Penny's Bay	Yam O
Chemical Oxygen Demand (mg kg^{-1})	35,100	51,900
Ammoniacal Nitrogen (mg kg^{-1})	40	78
Total Kjeldahl Nitrogen (mg kg^{-1})	1,590	1,040
Copper (mg kg^{-1})	85	502

Testing Parameter	Penny's Bay	Yam O
Total PAHs (μg kg^{-1})	<8,000	<8,000
Total PCBs (μg kg^{-1})	<100	<100
TBT (μg kg^{-1})	11	39

5.5.10 The sediment oxygen demand was used to determine the reductions in dissolved oxygen concentration, based on the calculated suspended sediment concentrations resulting from the dredging and filling at the Penny's Bay and Yam O reclamations. The reductions were then compared with the ambient levels at Stations SM10, WM4 and NM1 from the EPD routine monitoring data to determine the relative effects of the increases in suspended sediment concentrations on dissolved oxygen.

5.5.11 At Stations SM10, WM4 and NM1 the WQO for depth averaged dissolved oxygen concentrations was breached in 1998, with values of only 3.9 mg L^{-1}, 3.2 mg L^{-1} and 3.5 mg L^{-1} being exceeded on 90% of the sampling occasions respectively. An examination of the routine EPD water quality monitoring data for the years 1999 to 1995 (12) found that the values measured in 1998 represented abnormally low dissolved oxygen values and in 1999 the values had increased to be in compliance with the WQO, although they were still lower than in previous years. It is proposed that the assessment of impacts be based on the background values in 1999 as these are more likely to be representative of the area surrounding the Theme Park reclamations, rather than the unrepresentative values measured in 1998. In 1999 the concentrations of dissolved oxygen, which were exceeded on 90% of the sampling occasions, were 4.2 mg L^{-1}, 4.9 mg L^{-1} and 4.6 mg L^{-1} at Stations WM4, SM10 and NM1 respectively.

5.5.12 The assessment of nutrient impacts from increased suspended sediment concentrations has been based on the sediment and water quality parameters of total inorganic nitrogen and ammonia. The concentrations of total inorganic nitrogen and ammonia have been used to determine increases in these parameters in the receiving waters, based on the calculated suspended sediment concentrations. These increases have then been compared with the ambient levels at Stations SM10, WM4 and NM1 to determine the relative effects of the increases in suspended sediment concentrations on total inorganic nitrogen and ammonia concentrations, which could then be converted to unionised ammonia.

5.5.13 Based on EPD routine water quality monitoring data for 1998 (13), the mean depth averaged total inorganic nitrogen concentrations at Stations SM10, WM4 and NM1 were 0.27 mg L^{-1}, 0.29 mg L^{-1} and 0.43 mg L^{-1} respectively. It should be noted that the WQO for total inorganic nitrogen is already breached at Station SM10 has been breached for the last 10 years of monitoring; concentrations at Station WM4 are within the WQO. The mean depth averaged unionised ammonia concentrations at Stations SM10, WM4 and NM1 were 0.003 mg L^{-1}, 0.005 mg L^{-1} and 0.005 mg L^{-1} respectively, determined from EPD routine water quality monitoring data for 1998 (14).

5.5.14 The sediment to be dredged at both Penny's Bay and Yam O would be classed as contaminated according to EPD's *Technical Circular No 1-1-92*, based on copper concentrations of 85 mg kg^{-1} and 502 mg kg^{-1} for Penny's Bay and Yam O respectively. It is therefore proposed that, of the metals tested, only the release of copper to the receiving

(12) Personal correspondence with EPD.
(13) EPD (1999). *Op cit*.
(14) EPD (1999). *Op cit*.

waters be considered as this is the only metal found in the sediment at levels high enough to be of concern. There are currently no Hong Kong specific criteria governing levels of concern for PAHs, PCBs and TBT in sediment and as such it is proposed to assess the release of these pollutants to the water column. The release of copper, PAHs, PCBs and TBT to the receiving waters has been estimated based on the calculated suspended sediment concentrations and a partitioning coefficient between the adsorbed and desorbed phases of these pollutants associated with the sediment.

5.5.15 At present there are no standards for Hong Kong governing the allowable concentrations of copper, PAHs, PCBs and TBT in marine waters and so reference has been made to the European Community water quality standards[(15)]. These standards specify allowable levels of copper, PAHs and TBT. It is noted that the European Community standards for TBT are stringent and may not necessarily be applicable to Hong Kong waters but are used here to maintain consistency with the other quoted standards. There are no standards specified for PCBs in marine waters and allowable levels have been derived from work published in the US [(16)] . In order to determine whether the increases in copper, PAHs, PCBs and TBT concentrations in the receiving waters are acceptable it is necessary to obtain an estimate of the ambient levels in the marine water. As part of a recent study of dredging an area of Kellett Bank [(17)] a review was made of data collected as part of the *SSDS Stage I Baseline Monitoring and Performance Verification.* It was determined that the mean copper concentration in the marine waters was 2.51 $\mu g\ L^{-1}$. This data represents concentrations in the vicinity of the SSDS Stage I outfall, but in view of a lack of such data in the vicinity of the Theme Park reclamations in Penny's Bay and Yam O, this value has been used in this assessment. Data on background levels in marine water of TBT has been obtained from the study *A Study of Tributyltin Contamination of the Marine Environment of Hong Kong* [(18)] . In this study data was obtained in the vicinity of Yam O and North Tsing Yi. These data were obtained in the vicinity of shipyard works and as such will be applicable to this study, given the proximity of the Penny's Bay reclamation to the Cheoy Lee Shipyard and the proximity of the Yam O reclamation to the floating dry docks moored offshore. The monitoring data determined representative concentrations of TBT in the marine waters of 0.01 $\mu g\ L^{-1}$ at North Tsing Yi and 0.009 $\mu g\ L^{-1}$ at Yam O. The North Tsing Yi data will be used in the assessment of the impacts of the Penny's Bay reclamation as this is the closest monitoring station. There is currently no data on the background levels of PAHs, PCBs in marine waters and as such it will only be possible to compare the predicted increase in concentrations with the relevant standards. The relevant standards and background concentrations are summarised in *Table 5.5c*.

Table 5.5c - Summary of Assessment Standard Pollutant Concentrations in Water (mg L^{-1}) and Background Concentrations (mg L^{-1})

Parameter	Assessment Standard	Background Concentration
Copper	5	2.51
Total PAHs	0.2	No data
Total PCBs	0.014	No data

(15) HMIP (1994). Environmental Economic and BPEO Assessment Principles for Integrated Pollution Control. Environmental Quality Standards and Assessment Levels for Surface Water.
(16) Sittig (1981).
(17) ERM (1999). Environmental Impact Assessment: Dredging an Area of Kellett Bank for Reprovisioning of Six Government Mooring Buoys. Final Report.
(18) Aspinwall Clouston Limited (1998). A Study of Tributyltin Contamination of the Marine Environment of Hong Kong. Final Report.

Parameter	Assessment Standard	Background Concentration
TBT	0.002	0.01 (Penny's Bay) 0.009 (Yam O)

5.5.16 It should be noted that the data in the above table show that the background concentrations of TBT already exceeds the stringent European Community criterion. However, the background levels in Hong Kong are typical of those measured in comparable marine waters around the world, such as major ports. It may be that the European Community criteria are not entirely applicable to Hong Kong, but are nevertheless used in this Study to provide a reference on the relative magnitudes of the release of TBT from sediments suspended during the dredging works.

Cumulative Impacts

5.5.17 If the suspended sediment plumes from the construction of the reclamations associated with the Project at Penny's Bay and Yam O were to overlap with those from other concurrent projects, there would be a potential for cumulative impacts. Such cumulative impacts could primarily occur in terms of elevated suspended sediment concentrations. Increases in suspended sediment concentrations from concurrent projects have been determined by reviewing computer modelling results of suspended sediment dispersion for these projects. The following concurrent projects with the potential for cumulative impacts have been identified:

- Dredging and filling at the Container Terminal 9 reclamation [19] ;
- Backfilling of South Tsing Yi and North Lantau Marine Borrow Areas with uncontaminated mud [20];
- Sand winning at the South Tsing Yi and West Sulphur Channel Marine Borrow Areas for the construction of the Container Terminal 9 reclamation [21];
- Sand winning at the East Lamma Channel Marine Borrow Areas for the Theme Park reclamation [22];
- Dredging and filling at the Sham Tseng Further Reclamation [23];
- Dredging at the Tang Lung Chau Dangerous Goods Anchorage [24];
- Dredging and filling at the Tsuen Wan Bay reclamation [25];
- Dredging and filling at the Lamma Extension power station reclamation [26];
- Dredging and filling at the Tung Chung and Tai Ho Further Development [27]; and
- Disposal of contaminated mud at the East Sha Chau Contaminated Mud Pits [28].

5.5.18 There is also a potential for cumulative impacts with the construction of the Route 10 Toll Plaza in the vicinity of the Fa Peng headland.

(19) ERM (1998). Environmental Impact Assessment: Dredging and Area of Kellett Bank for Reprovisioning of Six Government Mooring Buoys. Final Report.
(20) ERM (1995). Backfilling of South Tsing Yi and North of Lantau MBAs. Final Environmental Impact Assessment.
(21) Scott Wilson Kirkpatrick (1994). Agreement No CE 52/94. West of Sulphur Channel Marine Borrow Area. Focused Environmental Impact Assessment. Final Report.
(22) Scott Wilson Kirkpatrick (1994). *Op cit*.
(23) Scott Wilson (Hong Kong) Ltd (2000). Agreement No CE 93/97. Planning and Engineering Feasibility Study for Development on Sham Tseng Further Reclamation. Draft EIA - Final Report (in preparation).
(24) Maunsell Consultants Asia Ltd (1999). Tsuen Wan Bay Further Reclamation, Area 35. Engineering, Planning and Environmental Investigation. Volume 1 of 3 : Tang Lung Chau Dangerous Goods Anchorage EIA Final Assessment Report.
(25) ERM (1998). Kowloon-Canton Railway Corporation, West Rail. Final Assessment Report. West Kowloon to Tuen Mun Centre. Contract No TS-900. Environmental Impact Assessment.
(26) ERM (1999). Environmental Impact Assessment of a 1,800 MW Gas-Fired Power Station at Lamma Extension. Final Report.
(27) Mott Connell Ltd (1999). Agreement No CE 1/97. Remaining Development in Tung Chung and Tai Ho. Comprehensive Feasibility Study. Environmental Studies. Final Assessment Report.
(28) ERM (19997). Environmental Impact Assessment Study for Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit. Final Report.

Reclamation Phasing

5.5.19 During the construction of the reclamation there may be the potential for the formation of embayed areas. Such areas would have low rates of exchange with the outside marine waters and the residence times of pollutants would be long. There would be the potential for poor water quality conditions to occur.

LAND BASED CONSTRUCTION ACTIVITIES

5.5.20 During land based construction activities for the Theme Park and for the road and rail links, the primary sources of potential impacts to water quality will be from pollutants in site run-off, which may enter marine waters directly or enter the storm drain system which discharges into these waters. Pollutants, mainly suspended sediments, may also enter the receiving waters if pumped groundwater is not adequately controlled.

5.5.21 Wastewater from temporary site facilities should be controlled to prevent direct discharge to marine waters adjacent to the reclamation. Such wastewater may include sewage effluent from toilets and discharges from on-site kitchen facilities. Water from plant servicing facilities may be contaminated with oil and other petroleum products and would have the potential to discharge to surface waters if spillages are not contained.

5.6 ASSESSMENT OF ENVIRONMENTAL IMPACTS - CONSTRUCTION

5.6.1 The assessment of the impacts to water quality during the construction phase has been divided into two aspects, formation of the reclamation and construction activities on land.

RECLAMATION FORMATION

5.6.2 The assessment of impacts from the construction of the Penny's Bay and Yam O reclamations is split into three aspects; suspended sediment concentrations, sediment deposition and chemical effects. Potential impacts on ecological resources as a result of reclamation construction activities are covered under *Section 8*.

Suspended Sediment Concentrations

PREVIOUS STUDIES

5.6.3 Computer modelling of a range of different dredging and filling rates was undertaken as part of the EIA study for *Design of Reclamation and Edge Structures for Container Terminals 10 and 11* (29). The scenarios simulated dredging and filling for the Container Terminals 10 and 11 reclamation at Penny's Bay and dredging for an access channel to the terminals and for a breakwater to provide shelter to the terminals. Four of the computer modelling scenarios are considered to be applicable for this Project in determining the impacts from the Penny's Bay reclamation in terms of suspended sediment concentrations. The scenarios may be summarised as follows.

- Scenario 1 simulated dredging for Container Terminal 10 berth 1, Container Terminal 11 and the access channels, assuming a fully dredged reclamation;
- Scenario 2 simulated dredging for Container Terminal 10 berth 1, Container Terminal 11 and the access channels, assuming a drained reclamation;
- Scenario 3 simulated the maximum combined dredging and filling for Container Terminals 10 and 11 and the access channels, assuming a fully dredged reclamation; and
- Scenario 4 simulated the highest rates of filling for Container Terminals 10 and 11, assuming a drained reclamation.

5.6.4 The above scenarios will be applicable for comparison with the proposed construction programme for the Theme Park reclamation in Penny's Bay, which will involve dredging and filling in broadly similar areas to those simulated previously. A fifth scenario was simulated in the previous study to represent dredging and filling at an intermediate stage of construction, ie with some of the seawalls already constructed. This scenario will not be suitable for comparison purpose because the sequence of construction of the seawalls will be different in this Study.

5.6.5 The predicted maximum elevations in suspended sediment concentrations at the identified sensitive receivers (see *Section 5.3.3*) in each of the wet and dry seasons are presented in *Tables 5.6a* and *5.6b* respectively. The tables show that the total loss rate of suspended sediments, which were used as input data to the computer modelling.

Table 5.6a - Maximum Predicted Elevations in Suspended Sediment Concentrations at Sensitive Receivers (mg L^{-1}) in the Dry Season

Sensitive Receiver	Scenario (Loss Rate in kg s^{-1})			
	1 (32.0)	2 (9.4)	3 (46.5)	4 (24.8)
Ma Wan Fish Culture Zone	2.6	1.1	7.8	4.2
Tung Wan Beach, Ma Wan	0.4	0.2	1.3	0.7
Sze Pak Wan	1.1	0.1	0.4	0.3
Discovery Bay Beach	0.1	0.0	0.1	0.1
Kau Yi Chau	0.0	0.0	0.1	0.0
Silvermine Bay Beach	0.0	0.0	0.0	0.0

Notes :
1. Shaded cells indicate exceedance of the WQO (see *Table 5.4a*)

(29) Maunsell Consultants Asia Ltd (1995). *Op cit.*

Table 5.6b - Maximum Predicted Elevations in Suspended Sediment Concentrations at Sensitive Receivers (mg L^{-1}) in the Wet Season

Sensitive Receiver	Scenario (Loss Rate in kg s^{-1})			
	1 (32.0)	2 (9.4)	3 (46.5)	4 (24.8)
Ma Wan Fish Culture Zone	1.7	0.3	4.9	3.0
Tung Wan Beach, Ma Wan	1.1	0.4	2.3	1.3
Sze Pak Wan	0.3	0.2	0.5	0.4
Discovery Bay Beach	0.0	0.0	0.1	0.1
Kau Yi Chau	0.0	0.2	1.1	0.7
Silvermine Bay Beach	0.0	0.0	0.0	0.0

Notes :

1. Shaded cells indicate exceedance of the WQO (see *Table 5.5a*)

5.6.6 The data in the above tables indicates that the computer modelling in the previous study for Container Terminals 10 and 11 predicted exceedances of the WQO for suspended sediment at the Ma Wan Fish Culture Zone in both the wet and dry seasons for the highest combined rates of dredging and filling in Scenario 3. At all other sensitive receivers in both seasons and for all scenarios compliance with the WQO was predicted.

5.6.7 Scenarios 1 and 2 simulated the rates of dredging during the early phases of construction for a fully dredged and drained reclamation respectively. Scenario 3 simulated the maximum combined dredging and filling rates for a fully dredged reclamation, and Scenario 4 simulated the maximum filling rate for a drained reclamation.

PENNY'S BAY RECLAMATION

5.6.8 The proposed construction programme for the dredging, seawall construction and filling for Phases I and II of the Theme Park reclamation in Penny's Bay is shown in *Figure 5.6a*; the reference working areas are identified in *Figure 5.6b* The programme shows that there will be considerable overlap in the dredging and filling activities, particularly during the early stages of the Phase I reclamation as this will be a fully dredged reclamation. This means that the greatest volumes of dredging and filling will be required during the Phase I reclamation. Examination of a detailed breakdown of the plant requirements [30] indicates that the highest rate of dredging will occur during Month 4 (August 2000), while the highest rate of filling will occur during Month 10 (February 2001) of the proposed construction programme. The construction programme has been designed such that these rates of working will not be exceeded. The numbers of plant, rates of working and areas of working at these times are summarised in *Tables 5.6c* and *5.6d*, the locations of the areas of working are shown in *Figure 5.6b*. It should be noted that during the time of maximum dredging there will be concurrent filling and during the time of maximum filling there will be concurrent dredging.

(30) Information provided by Scott Wilson (Hong Kong) Ltd, who are the project engineers for the Penny's Bay reclamation.

Table 5.6c - Summary of Plant Operating During Month 4 of the Construction Programme (Maximum Dredging)

Plant Type	Nominal Rate of Working (m^3 week^{-1})	Number of Plant	Areas of Working	Cumulative Rate of Working (m^3 week^{-1})
Dredging				
TSHD 8000	112,400	3	Q07, Q02	337,200
TSHD 5000	66,800	1	Q07	66,800
Grab Full	60,000	3	P01,P03, Q01	180,000
Grab Clean	25,000	2	P01, Q07	50,000
Filling				
TSHD 8000	165,800	2	Q04, Q07	331,600

Notes:
1. TSHD 8000 refers to an 8,000 m^3 capacity trailing suction hopper dredger.
2. TSHD 5000 refers to an 5,000 m^3 capacity trailing suction hopper dredger.
3. Grab Full refers to an 8.5 m^3 grab dredger working at full rate.
4. Grab Clean refers to an 8.5 m^3 grab dredger working at a reduced rate on trimming activities.

Table 5.6d - Summary of Plant Operating During Month 10 of the Construction Programme (Maximum Filling)

Plant Type	Nominal Rate of Working (m^3 week^{-1})	Number of Plant	Areas of Working	Cumulative Rate of Working (m^3 week^{-1})
Dredging				
TSHD 8000	112,400	2	Q06	224,800
TSHD 5000	66,800	1	Q06	66,800
Grab Full	60,000	3	Q08, Q06,	180,000
Grab Clean	25,000	2	Q08, Q06,	50,000
Filling				
TSHD 8000	165,800	6	P03, Q08, Q06, Q11, Q03	994,800

Notes:
1. TSHD 8000 refers to an 8,000 m^3 capacity trailing suction hopper dredger.
2. TSHD 5000 refers to an 5,000 m^3 capacity trailing suction hopper dredger.
3. Grab Full refers to an 8.5 m^3 grab dredger working at full rate.
4. Grab Clean refers to an 8.5 m^3 grab dredger working at a reduced rate on trimming activities.

5.6.9 In order to compare the proposed rates of working with the modelling predictions in the previous study for Container Terminals 10 and 11 it is necessary to determine the loss rates of fines to suspension from the activities described in *Tables 5.6c* and *5.6d*. This will then enable a direct comparison with the loss rates and the modelling predictions shown in *Tables 5.6a* and *5.6b*.

5.6.10 For studies assessing the impacts of dredging areas of Kellett Bank for mooring buoys, estimates of the loss rates from grab dredging and dredging using trailing suction hopper dredgers were made [31] [32]. For these two previous studies, the estimates of loss rate were made based on an extensive review of world wide data on loss rates from dredging operations. The assessment concluded that for 8 m^3 grab dredgers working in areas with significant amounts of debris on the sea bed (such as in the vicinity of existing mooring

(31) ERM (1997). Environmental Impact Assessment: Dredging an Area of Kellett Bank for Reprovisioning of Six Government Mooring Buoys. Working Paper on Design Scenarios.

(32) Babtie BMT Harris & Sutherland (1998). Supplementary Agreement No 1 to Agreement No CE 31/96. Green Island Development - Studies on Ecological, Water Quality and Marine Traffic Impacts. Dredging Study for New Fairway and Reprovisioning of Mooring Buoys. Working Paper for Dredging and Disposal Scheme.

buoys) that the loss rates would be 25 kg m^{-3} dredged, while the loss rate in areas where debris is less likely to hinder operations would be 17 kg m^{-3} dredged. For this Study it is proposed that the loss rate of 17 kg m^{-3} dredged for grab dredging be used as there are unlikely to be significant quantities of debris in the vicinity of the dredging works due to the fact that there are no existing mooring buoys or port facilities.

5.6.11 A review of international data on losses from trailer dredgers in the previous study for dredging Kellett Bank (33) determined that a loss rate of 7 kg m^{-3} dredged would be appropriate irrespective of the size of the dredger, assuming no overflowing but that the Lean Mixture Overboard (LMOB) systems are in operation. LMOB is used at the beginning and end of the dredging cycle when the suction arm is being lowered and raised. At these times the majority of the material entering the hopper will be water with small amounts of fine sediments, which is discharged to the sea via the overflow system. Overflowing refers to the discharge of fine sediment and water during bulk dredging and results in high losses of sediment to suspension. Overflowing is not usually permitted when dredging in marine mud and is usually only allowed during dredging of sand deposits, when overflowing is utilised to increase the density of the material in the hopper. The value of 7 kg m^{-3} dredged for dredging using trailing suction hopper dredgers will be appropriate for this Study as LMOB will be used but overflowing will not be permitted.

5.6.12 The calculation of the loss rate from filling activities is more complicated and is based on an approach developed during the assessment of the proposed Kowloon Point Reclamation (34). This method of calculation of loss rate is summarised as follows:

- A series of trial uncontaminated marine mud disposal events were carried out at the East Tung Lung Chau Marine Borrow Area (35) and it was determined that the representative loss rate of fines to suspension from bottom dumping was 5%;
- The material disposed of at the east Tung Lung Chau MBA consisted of approximately 60% fines;
- By taking the fines content of the sand fill material for this Study and using a simple pro-rata basis of fines content divided by 60%, and multiplying by 5% gives the percentage loss rate from sand filling for this Study;
- A representative dry density of the sand fill in the hopper of the trailer dredger should be taken as being 1,400 kg m^{-3}; and
- The loss rate in kg s^{-1} is calculated by multiplying the percentage loss rate by the volume rate of filling multiplied by the dry density of the sand fill.

5.6.13 The sand fill for the reclamation will be obtained from marine borrow areas by trailing suction hopper dredgers. It is currently proposed that the majority of the sand fill material will be obtained from the Weilingding Marine Borrow Area, which is on mainland Chinese waters. The *in situ* fines content of the sand in the borrow area varies between 2% to 30% (36) , with the upper values representing marine sand deposits and the lower values found in the alluvial deposits. Whilst dredging the sand, particularly the marine sand deposits, the dredgers will be permitted to overflow to reduce the fines content of the

(33) ERM (1997). Op cit.
(34) Kowloon Point Development Feasibility Study. Environmental Impact Assessment.
(35) Dredging Research Ltd (1996). Measurements of Sediment Transport after Dumping from Trailing Suction Hopper Dredgers in the East Tung Lung Chau Marine Borrow Area. Report to GEO/CED.
(36) Communication with DEMAS dredging consultants.

material in the hopper. It is estimated that a fines content of 3% to 8% [37] can be achieved in the material in the hopper of the dredger. A small portion of the sand fill material is likely to be obtained from the East Lamma Channel Marine Borrow Area. The *in situ* fines content of the sand is 4% to 6% [38] [39] , which will be the fines content of the material delivered to the reclamation site because overflowing is prohibited at this borrow area. It is proposed that the upper bound of 8% on the fines content be used to calculate the loss rate to ensure a suitably conservative assessment.

5.6.14 The calculated loss rates for the dredging and filling rates shown in *Tables 5.6c* and *5.6d* are presented in *Tables 5.6e* and *5.6f* for the maximum rates of dredging and filling respectively. It has been assumed that 24 hour working will be undertaken 7 days per week for both dredging and filling. The loss rates presented in *Tables 5.6e* and *5.6f* thus represent the average daily values.

Table 5.6e - Calculated Loss Rates of Fine Sediment to Suspension During Month 4 of the Construction Programme (Maximum Dredging)

Plant Type	**Rate of Working (m^3 $week^{-1}$)**	**Rate of Working (m^3 s^{-1})**	**Loss Rate (kg s^{-1})**
Dredging			
TSHD 8000	337,200	0.5575	3.9
TSHD 5000	66,800	0.1104	0.8
Grab Full	180,000	0.2976	5.1
Grab Clean	50,000	0.0827	1.4
Filling			
TSHD 8000	331,600	0.5439	5.1
Total Loss Rate			**16.3**

Notes:
1. TSHD 8000 refers to an 8,000 m^3 capacity trailing suction hopper dredger.
2. TSHD 5000 refers to an 5,000 m^3 capacity trailing suction hopper dredger.
3. Grab Full refers to an 8.5 m^3 grab dredger working at full rate.
4. Grab Clean refers to an 8.5 m^3 grab dredger working at a reduced rate on trimming activities.

Table 5.6f - Calculated Loss Rates of Fine Sediment to Suspension During Month 10 of the Construction Programme (Maximum Filling)

Plant Type	**Rate of Working (m^3 $week^{-1}$)**	**Rate of Working (m^3 s^{-1})**	**Loss Rate (kg s^{-1})**
Dredging			
TSHD 8000	224,800	0.3717	2.6
TSHD 5000	66,800	0.1104	0.8
Grab Full	180,000	0.2976	5.1
Grab Clean	50,000	0.0827	1.4
Filling			
TSHD 8000	994,800	1.6448	15.4
Total Loss Rate			**25.3**

Notes:
1. TSHD 8000 refers to an 8,000 m^3 capacity trailing suction hopper dredger.
2. TSHD 5000 refers to an 5,000 m^3 capacity trailing suction hopper dredger.
3. Grab Full refers to an 8.5 m^3 grab dredger working at full rate.
4. Grab Clean refers to an 8.5 m^3 grab dredger working at a reduced rate on trimming activities.

5.6.15 In order to calculate the impacts at sensitive receivers based on the above loss rates it is proposed to use a pro rata calculation based on Scenario 3 of the previous modelling, the results from which are presented in *Tables 5.6a* and *5.6b*. This scenario is considered to be

(37) Communication with DEMAS dredging consultants.
(38) Binnie Consultants Ltd (1993). East Lamma Channel Borrow Area Scoped Environmental Assessment. Final Report.
(39) Communication with DEMAS dredging consultants.

the most appropriate from the previous modelling work because it represented the highest combined dredging and filling rates, which provides the closest analogy to the assessment for this Study. The results of the calculated increases in suspended sediment concentrations are given in *Tables 5.6g* and *5.6h* for the maximum dredging and filling rates respectively.

Table 5.6g - Calculated Elevations in Suspended Sediment Concentrations at Sensitive Receivers (mg L^{-1}) for the Maximum Rate of Dredging

Sensitive Receiver	WQO Allowable Elevation in Suspended Sediment Concentration (mg L^{-1})		Calculated Elevations in Suspended Sediment Concentrations (mg L^{-1})	
	Wet Season	Dry Season	Wet Season	Dry Season
Ma Wan Fish Culture Zone	3.2	4.5	1.7	2.7
Tung Wan Beach, Ma Wan	3.2	4.5	0.8	0.5
Sze Pak Wan	3.3	3.8	0.2	0.1
Discovery Bay Beach	3.3	3.8	0.0	0.0
Kau Yi Chau	10.6	3.8	0.4	0.0
Silvermine Bay Beach	5.4	3.8	0.0	0.0

Table 5.6h - Calculated Elevations in Suspended Sediment Concentrations at Sensitive Receivers (mg L^{-1}) for the Maximum Rate of Filling

Sensitive Receiver	WQO Allowable Elevation in Suspended Sediment Concentration (mg L^{-1})		Calculated Elevations in Suspended Sediment Concentrations (mg L^{-1})	
	Wet Season	Dry Season	Wet Season	Dry Season
Ma Wan Fish Culture Zone	3.2	4.5	2.7	4.2
Tung Wan Beach, Ma Wan	3.2	4.5	1.3	0.7
Sze Pak Wan	3.3	3.8	0.3	0.6
Discovery Bay Beach	3.3	3.8	0.1	0.1
Kau Yi Chau	10.6	3.8	0.6	0.0
Silvermine Bay Beach	5.4	3.8	0.0	0.0

5.6.16 The data in *Tables 5.6g* and *5.6h* predict that the Water Quality Objective for suspended sediment concentrations will not be breached at any of the identified sensitive receivers in the vicinity of the Penny's Bay reclamation.

5.6.17 The above assessment for the impacts during Month 10 of the construction programme is likely to be somewhat conservative. This is because the seawalls in Section Q4 and a large part of Section Q7 (see *Figure 5.6b*) will have been completed prior to commencing this rate of working (see *Figure 5.6a*). The construction of these seawalls will mean that the reclamation area will be partially sheltered from tidal currents on the flood tide, which would be responsible for carrying the sediment plumes towards the Ma Wan Fish Culture Zone. This would mean that the impacts are likely to be lower than those predicted above, which have been shown to be acceptable despite the conservative nature of the assessment.

5.6.18 During the filling operations it is proposed to make use of cutter suction dredgers operating in a rehandling basin. During the initial phases of reclamation construction the rehandling basin is planned to be situated in the north eastern corner of area Q6 (see *Figure 5.6b*). This area is within Penny's Bay and as such the tidal currents are very low. The cutter suction dredger will commence work in Month 6 of the construction programme, when the seawalls for Section Q4 (see *Figures 5.6a* and *5.6b*) will have largely been completed. This will mean that the rehandling basin will be further sheltered from tidal currents. As the reclamation construction progresses from west to east the rehandling basin will move with the leading face of the reclamation. However, the construction of the seawalls will progress concurrently with the reclamation formation. The rehandling basin will, therefore, always be sheltered from tidal currents, provided that the seawalls are constructed in advance of the position of the re-handling basin. The above described factors should ensure that any sediment lost to suspension during the operation of the cutter suction dredger in the rehandling basin will not be transported beyond the immediate vicinity of the works area and, as such, adverse impacts at sensitive receivers, notably the Ma Wan Fish Culture Zone, are not expected. In order to further ensure that there are no adverse impacts, it is recommended that measures are implemented to minimise the loss of fine sediment to suspension during the operation of the cutter suction dredger in the rehandling basin and these are detailed in *Section 5.7.1*.

YAM O RECLAMATION

5.6.19 The Yam O reclamation will be constructed at a much slower rate than the Penny's Bay reclamation. Dredging will only be required along the line of the seawalls and will be carried out by a single 8.5 m^3 grab dredger working at a rate of 2,000 m^3 day^{-1}. Sand filling will be carried out by bottom dumping from split barges at a rate of working of 14,000 ^{3} day^{-1}. The construction programme is such that sand filling will only take place behind seawalls, which have reached the stage of construction where they break the water surface. Any losses of fine sediment to suspension during sand filling should be contained by the seawalls and would therefore not be expected to impact the receiving waters outside of the reclamation works. Therefore dredging will be the only source of suspended sediment with the potential to impact sensitive receivers. Based on the calculation method described above for the Penny's Bay reclamation, the loss rate from grab dredging will be 0.39 kg s^{-1}.

5.6.20 The method of calculation of the near field concentrations of suspended sediment plumes is the same as was used in the *Design of Reclamation and Edge Structures for Container Terminals 10 and 11* (40). In this method, a simple model is used to calculate the depth averaged suspended sediment concentrations along the centreline of a plume by solving the advection-diffusion equation for a continuous line source (41). This model is considered appropriate for the calculation of suspended sediment concentrations from the Yam O reclamation dredging because the equation is based on a continuous line source of sediment, which is a reasonable approximation of the loss of sediment to suspension during grab dredging. It is appropriate for areas where the tidal current is uni-directional for each phase of the tidal cycle (ie the ebb and flood phases), which is the case at Yam O where the currents generally follow the coastline. This method is applicable for suspended sediment plumes of length no greater than the maximum tidal excursion. At the Yam O site the maximum tidal current speeds may be up to 0.5 m s^{-1} and a representative period for each phase of the tidal cycle in Hong Kong is 6 hours. The tidal excursion may be calculated according to the following equation.

(40) Maunsell Consultants Asia Ltd (1995). *Op cit.*
(41) R E Wilson. A Model for the Estimation of the Concentrations and Spatial Extent of Suspended Sediment Plumes. Estuarine and Marine Coastal Science (1979), Vol 9, pp 65-78.

Tidal excursion = maximum speed * period * $2/\pi$

5.6.21 The tidal excursion is thus calculated to be 6.9 km and hence this approach may be considered appropriate because of the low rate of dredging and thus the expected limited extent of the plumes, which will certainly be within the tidal excursion. The formula which is used is as follows.

$$C(x) = q/(D*x*\omega*\sqrt{\pi})$$

where $C(x)$ = concentration at distance x from the source
q = sediment loss rate = 0.39 kg s^{-1}
D = water depth = 15 m
x = distance from source
ω = diffusion velocity = 0.01 m s^{-1}

5.6.22 The representative water depth along the direction of dispersion of the sediments suspended during dredging, varies from approximately 15 m to 20 m. For the calculation of suspended sediment concentrations, a depth of 15 m has been selected to give a worst case assessment as concentration is inversely proportional to depth. The value for diffusion velocity is the same as that which was used in the previous study for the near field assessment of sediment plumes from the construction of Container Terminals 10 and 11 (42) and is considered appropriate for use in this Study, given the proximity of the Yam O reclamation to those considered previously. The diffusion velocity represents reductions in the centre-line concentrations due to lateral spreading.

5.6.23 The use of the above equation is limited to situations where the value of γ, as defined by the following equation, is small and where ω/u is also small.

$$\gamma = Wt/D$$

where W = settling velocity of suspended sediment
t = time
D = water depth = 15 m

5.6.24 The sediments suspended by the dredging operations may be split into a fine fraction and a coarse fraction. The fine fraction is assumed to remain in suspension indefinitely, which is based on the fact that the settling velocity for the sediment particles according to Stokes Law is offset by local turbulence. The settling velocity of the coarse fraction is taken to be 0.128 mm s^{-1}, as derived from Stokes Law for a particle size of 0.012 mm. This value was derived from the D_{75} diameter of a number of sediment samples from Penny's Bay (43), which assumes that the fine fraction is represented by the smallest 50% of the sample and the coarse fraction is represented by the largest 50%. The value for t is taken to be half of the tidal period, which may be taken to be the time between the ebb and flood phases of the tidal cycle. In Hong Kong this is greatest for the ebb phase of a spring tide where the time from high water to low water can be up to 8 hours. The value of γ for the coarse fraction of the suspended sediment is calculated to be 0.25, while for the fine fraction would approach zero. These values are small and as such the above equation would be valid for both the fine and coarse fractions. The average current speed in the vicinity of the Yam O works is taken to

(42) Maunsell Consultants Asia Ltd (1995). *Op cit*.
(43) Data provided by the Geotechnical Engineering Office of the Civil Engineering Department.

be 0.25 m s^{-1}, which means that the value of ω/u is calculated to be 0.04, which is considered to be small and the use of the above equation is considered valid.

5.6.25 The results of the calculation of suspended sediment concentrations are given in *Table 5.6i*.

Table 5.6I - Calculated Suspended Sediment Concentrations from the Dredging at the Yam O Reclamation

Distance from Source (m)	Suspended Sediment Concentration (mg L^{-1})
100	14.7
200	7.3
300	4.9
400	3.7
500	2.9
600	2.4
700	2.1
800	1.8

5.6.26 The closest identified sensitive receiver to the Yam O reclamation is the Ma Wan Fish Culture Zone, which is 2,800m from the dredging operations. The allowable increases in suspended sediment concentrations at this sensitive receiver are 4.5 mg L^{-1} in the dry season and 3.2 mg L^{-1} in the wet season (see *Table 5.5a*). The data is the above table predicts that at less than 500 m from the dredging operation, the suspended sediment concentrations will be below 3.2 mg L^{-1}. Predicted suspended sediment concentrations at the closest sensitive receiver are below the WQO.

5.6.27 The allowable increases in suspended sediment concentrations according to the WQO in the vicinity of the dredging works is 2.3 mg L^{-1} in the wet season and 3.2 mg L^{-1} in the dry season, derived from data at Station NM1. The data in *Table 5.6i* shows that at less than 700 m from the dredging works compliance with the WQO will be achieved. As discussed above, this area does not contain any sensitive receivers and as such the area of exceedance of the WQO could be classed as a ‘mixing zone’ and the predicted impacts would be deemed acceptable.

SEDIMENT DEPOSITION

Previous Studies

5.6.28 In the study *Design of Reclamation and Edge Structures for Container Terminals 10 and 11 and Back-up Areas* (44) the results of the computer modelling were analysed to produce contours of net deposition of fine sediment over a complete tidal cycle. The maximum rates of sediment deposition were found for Scenario 3, which, as discussed above, simulated the highest rates of sediment lost to suspension of 46.5 kg s^{-1}. The predicted rates of deposition were similar for both the wet and dry season tides. In the immediate vicinity of the dredging operation, rates of deposition exceeded 0.6 kg m^{-2} day^{-1} while rates of 0.2 kg m^{-2} day^{-1} to 0.4 kg m^{-2} day^{-1} were predicted to occur over an area of approximately 1.5 km by 3.5 km. This area encompassed the region of the Penny's Bay reclamation and seaward of the line of the seawalls and along the coastline of Lantau Island to the north east up to the Fa Peng headland. Deposition rates of less than 0.2 kg m^{-2} day^{-1} were predicted to occur south of the works areas, and affected the coastlines of outer Discovery Bay, Peng Chau, Siu Kau Yi Chau and the headland at the south western end of Penny's Bay. Elsewhere deposition rates were predicted to be less than 0.01 kg m^{-2} day^{-1}.

PENNY'S BAY

5.6.29 The maximum loss rate of sediment to suspension during the construction of the Penny's Bay reclamation for the Theme Park occurs at the time of the maximum rate of filling in month 10 of the construction programme. At this time, the loss of fine sediment to suspension has been calculated to be 25.3 kg s^{-1}, which is 54.4% lower than the maximum loss rate in the previous study. In assessing the impacts of suspended sediment concentrations on sensitive receivers for this Study the results from the previous modelling were reduced by 54.4%. The same approach has been used here to calculate the rates of sediment deposition from the filling and dredging at the Penny's Bay reclamation for the Theme Park. This approach is considered to be reasonable because rates of deposition are directly related to the quantities of sediment in suspension.

5.6.30 In the vicinity of the works area for the Penny's Bay reclamation, the rates of deposition are calculated to be 0.33 kg m^{-2} day^{-1}. In the area along the face of the reclamation and the north eastern coastline of Lantau Island up to the Tsing Chau Tsai headland the deposition rates are calculated to be in the range of 0.22 kg m^{-2} day^{-1} to 0.11 kg m^{-2} day^{-1}, which covers an area approximately 5 km long by 1.5 km wide. Within this area, only the deposition rates along the face of the reclamation area are predicted to exceed the threshold value of 0.2 kg m^{-2} day^{-1} for hard corals, while along the coastline of Lantau Island from the Pa Tau Kwu headland to the Fa Peng headland deposition rates are predicted to be lower than the threshold value. The area of exceedance of the threshold value is open seabed and, as such, deposition rates would not be considered to represent an adverse impact. Further afield, around Discover Bay, Peng Chau and Siu Kau Yi Chau, sediment deposition rates are calculated to be less than 0.11 kg m^{-2} day^{-1}, which is less than the critical value. Around Kau Yi Chau and at Sze Pak Wan sediment deposition rates are predicted to be less than 0.005 kg m^{-2} day^{-1}. No adverse impacts due to sediment deposition from the construction of the Penny's Bay reclamation for the Theme Park are therefore predicted.

(44) Maunsell Consultants Asia Ltd (1995). *Op cit*.

YAM O

5.6.31 The rate of deposition due to the sediment plumes from the dredging at Yam O may be determined by the following equation.

rate of deposition = average SS concentration * daily settling rate

5.6.32 The average suspended sediment concentration is determined from the calculated suspended sediment concentrations in *Table 5.6i*. The average suspended sediment concentration along the sediment plume is thus calculated to be 5.0 mg L^{-1}. The daily settling rate is calculated from the settling velocity for the coarse fraction of sediments, as discussed above, which is thus 11.1 m day^{-1}. The deposition rate is thus calculated to be 0.055 kg m-^{2} day^{-1}. This value is less than the critical value for corals of 0.2 kg m^{-2} day^{-1} and as such would not cause an adverse impact. It should be noted that the deposition will occur in an area which is not expected to contain hard corals. The predicted impacts due to sediment deposition from dredging at the Yam O reclamation are therefore considered to be acceptable.

WATER QUALITY

Previous Studies

5.6.33 In the study *Design of Reclamation and Edge Structures for Container Terminals 10 and 11 and Back-up Areas* (45) the results of computer modelling of sediment dispersion were used to calculate decreases in dissolved oxygen concentrations and increases in nutrient (total inorganic nitrogen) concentrations. Scenario 3 from the previous study has again been used as the reference scenario since it simulated the highest loss of sediment to suspension of 46.5 kg s^{-1}.

5.6.34 The previous results predicted that the greatest decreases in dissolved oxygen levels would occur during the dry season and it is these results which have been considered here. The modelling predicted that in the vicinity of the works area the maximum depletion in dissolved oxygen concentration would be 0.06 mg L^{-1}, while in the region around the works area and along the north eastern coast of Lantau Island, decreases in dissolved oxygen were predicted to be in the range 0.04 to 0.02 mg L^{-1}. Further from the works area, in Sze Pak Wan, Discovery Bay, Peng Chau and around Ma Wan Island, depletions in dissolved oxygen concentration were less than 0.02 mg L^{-1}. In the previous modelling it was assumed that the oxygen demand of the sediment was 22,500 mgO kg^{-1} sediment, which was based on typical values recorded in Victoria Harbour.

5.6.35 The previous modelling predicted that the increases in nutrient levels would be similar for both the wet and dry seasons. The maximum increases in nutrient concentrations were predicted to be in excess of 0.01 mg L^{-1} in the immediate vicinity of the dredging operations. In the area along the seaward face of the reclamation and off the north eastern coast of Lantau Island the predicted increases in nutrient concentrations were in the range of 0.0025 mg L^{-1} to 0.005 mg L^{-1}. The remainder of the predicted increases in nutrient levels were less than 0.0025 mg L^{-1} and were only predicted to effect the open water to the south and south east of the reclamation site and the coastlines of north east Lantau Island and Tang Lung Chau. The modelling assumed that the nutrient content of the sediments was 500 mg N kg^{-}

(45) Maunsell Consultants Asia Ltd (1995). *Op cit.*

[1]sediment, which was based on the upper bound of sediment quality values in Victoria Harbour.

PENNY'S BAY

5.6.36 In order to predict the effects of the loss of sediment to suspension from the dredging and filling for the Penny's Bay reclamation on oxygen concentrations, the results from the previous modelling have been factored by the ratio of the loss rate from the Penny's Bay reclamation to the loss rate in the previous modelling (ie 25.3/46.5) and by the ratio of the sediment oxygen demand values (ie 35,100/22,500). This gives an overall factor of 0.85. This is considered to be a reasonable approach to adopt because decreases in dissolved oxygen concentrations are directly related to suspended sediment concentration and sediment oxygen demand. It should be noted however, that this approach is inherently conservative because the sediment lost to suspension is composed of that lost from dredging and that lost from sand filling. The fines content of the sand filling material is likely to have a considerably lower oxygen demand that the sediment being dredged and so applying the same sediment oxygen demand to all of the fine sediment lost to suspension (ie that of the sediment to be dredged) will lead to a conservative assessment.

5.6.37 The dissolved oxygen depletion from the loss of sediment to suspension during the construction of the Penny's Bay reclamation for the Theme Park is calculated to be greater then 0.051 mg L^{-1} in the vicinity of the works, while decreases over a wider area, including a portion of the coastline of north east Lantau Island are predicted to be in the range of 0.034 to 0.017 mg L^{-1}. Further from the works area, in Sze Pak Wan, Discovery Bay, Peng Chau and around Ma Wan Island, the reductions in dissolved oxygen levels are predicted to be less than 0.017 mg L^{-1}. The background dissolved oxygen values, which are considered in this assessment, are 4.2 mg L^{-1} and 4.9 mg L^{-1} at Stations WM4 and SM10 respectively. In the immediate vicinity of the works the sediment plumes will be closest to Station SM10, and the maximum depletion in dissolved oxygen concentrations constitutes 1% of the background and the predicted depletion would not cause a breach of the WQO. Further away from the works area the predicted depletion is less than 0.017 mg L^{-1}, which constitutes less than 0.5% of the background concentrations at Station WM4, the closest and most relevant station. The predicted depletion in dissolved oxygen concentrations would also not cause a breach in the WQO around Ma Wan Island. It should also be noted that the predicted depletions in dissolved oxygen concentrations would only persist during the maximum rates of dredging and filling, and at other times the reductions in dissolved oxygen concentrations would be less. It is concluded that there will be no adverse effects on dissolved oxygen concentrations as a result of the dredging and filling works at the Penny's Bay reclamation as the predicted depletions in dissolved oxygen concentrations would not cause a breach of the WQO.

5.6.38 In order to predict the effects of the loss of sediment to suspension from the dredging and filling for the Penny's Bay reclamation on nutrient concentrations, the results from the previous modelling have been factored by the ratio of the loss rate from the Penny's Bay reclamation to the loss rate in the previous modelling (ie 25.3/46.5) and by the ratio of the nutrient content of the sediment. Two factors are considered here, unionised ammonia and total inorganic nitrogen.

5.6.39 Ammoniacal nitrogen concentration has been calculated by taking the ratio of ammonia concentrations in the sediment to the assumed nitrogen content in the previous modelling, which is 40/500. In the vicinity of the dredging works, routine EPD water quality monitoring data for 1998 (46) has found that unionised ammonia is approximately 3.3% of the total ammonia concentration. The total factor for calculating unionised ammonia concentrations is thus 0.0014 (ie 25.3/46.5 x 40/500 x 0.033).

5.6.40 There is no data available on total inorganic nitrogen content of the sediments in Penny's Bay and as such, the total nitrogen concentration has been used; this provides a conservative estimate. The ratio of total nitrogen concentration in the sediment to that assumed in the previous modelling is 1,630/500. The total factor for calculating total nitrogen concentrations, which is equated to total inorganic nitrogen, is thus 1.77 (ie 25.3/46.5 x 1,630/500).

5.6.41 These assumptions for calculating nitrogen concentrations from the Penny's Bay reclamation are considered reasonable because the nitrogen concentrations are directly dependent upon the quantities of sediment lost to suspension and the nitrogen content of the sediments. It should be noted however, that this approach is inherently conservative because the sediment lost to suspension is composed of that lost from dredging and that lost from sand filling. The fines content of the sand filling material is likely to have a considerably lower nitrogen content than the sediment being dredged and so applying the same nitrogen content to all of the fine sediment lost to suspension (ie that of the sediment to be dredged) will lead to a conservative assessment.

5.6.42 The calculated increases in total nitrogen (equated here to total inorganic nitrogen) in the immediate vicinity of the works area are predicted to be in excess of 0.018 mg L^{-1}. Outside of the works area, and along the coast of north east Lantau Island, increases are predicted to be in the range of 0.004 to 0.009 mg L^{-1}. These areas are best represented by EPD routine water quality monitoring Station SM10, where the depth averaged total inorganic nitrogen concentrations were 0.27 mg L^{-1}. The predicted increases in the vicinity of the works area would only elevate the background levels by less than 7%; this is considered to represent a small increase. Further away from the works, increases due to the reclamation construction would elevate the background levels by 3.3%, which is considered to be negligible.

5.6.43 The assessment of the increases in total inorganic nitrogen levels has predicted that the dredging works will only increase the background levels by small amounts, despite the conservative nature of the assessment. The existing total inorganic nitrogen levels already breach the WQO and as such the water body would be considered to be 'stressed'. However, the predicted levels represent an insignificant increases compared to the background levels and will only persist as long as high rates of dredging and filling are maintained. The reclamation construction would thus not contribute significantly to the background concentrations nor would it prevent the long term recovery of the water body. The predicted increases in total inorganic nitrogen levels are therefore considered to be acceptable.

5.6.44 Increases in unionised ammonia in the immediate vicinity of the works area are predicted to be in excess of 0.000014 mg L^{-1}, which is extremely small. The background level of unionised ammonia at Station SM10, the closest EPD routine water quality monitoring station, was 0.003 mg L^{-1}. The addition of the unionised ammonia from the reclamation works will not significantly add to the background levels nor will the additional ammonia

(46) EPD (1999). *Op cit*.

cause the WQO of 0.021 mg L^{-1} be breached. Predicted increases in unionised ammonia levels are therefore considered to be acceptable.

5.6.45 In the previous studies for the Container Terminals 10 and 11 no modelling of the release of metals to the water column from the suspended sediments was carried out. The prediction of pollutant release to the water column for the Penny's Bay reclamation have therefore been based on the previous predictions of suspended sediment concentrations. The prediction of the release of metals has been based on the following equation, which has been used on previous projects in Hong Kong [47] [48] , and represents the partitioning of pollutants between the adsorbed and desorbed phases. This equation is applicable to determine partitioning of pollutants associated with cohesive sediments and is thus suitable for this Study. The equation describing the partitioning is as follows:

$$C_t = C_s + (C_s x K_d x SS)$$

Where C_s = concentration of metal in water (desorbed)
K_d = partitioning coefficient
SS = suspended sediment concentration
C_t = SS x C_{sed}
C_{sed} = concentration of metal in sediment

5.6.46 The value of the partitioning coefficient for copper was derived from the a previous study which assessed the environmental impacts of dredging Kellett Bank [49]. The values of the partitioning coefficients for PAHs and PCBs were derived from a previous study which assessed the environmental impacts of the disposal of contaminated mud at East Sha Chau [50]. There is, however, no simple partition coefficient for TBT and it is proposed to assume that all of the TBT is released, which will give a very conservative estimate. The concentration of copper, PAHs, PCBs and TBT in the sediment was derived from sediment quality monitoring data collected for this Study, as presented in *Table 5.5b*. It should be noted that for PAHs and PCBs the values were all below the detection limit and so the detection limit has been used in order to provide a conservative estimate of the release to the water column. The partition coefficients are summarised in *Table 5.6j*.

(47) ERM (1998). Environmental Impact Assessment : Dredging an Area of Kellett Bank for Reprovisioning of Six Government. Final Report.
(48) ERM (1997). Environmental Impact Assessment Study for Disposal of Contaminated Mud in the East Sha Chau Marine Borrow Pit. Final Report.
(49) ERM (1998). *Op cit*.
(50) ERM (1997). Op cit.

Table 5.6j - Partition Coefficients (L g^{-1}) for Pollutants in Sediment

Parameter	Partition Coefficient
Copper	122
Total PAHs	0.075
Total PCBs	1000
TBT	Assume all released

5.6.47 A review of the sediment dispersion modelling from the *Design of Reclamation and Edge Structures for Container Terminals 10 and 11 and Back-up Areas*[51] found that the maximum suspended sediment concentrations at the boundary of the works area was 15 mg L^{-1}. However, the loss rate of fine sediment to suspension for the construction of the Penny's Bay reclamation is 54.4% (25.3/46.5 kg s^{-1}) of that assumed for the previous study; it is therefore considered reasonable to assume that the suspended sediment concentrations will reduce by the same amount. On this basis, the maximum predicted suspended sediment concentration at the boundary of the works area for the construction of the Penny's Bay reclamation is 8.2 mg L^{-1}. The resulting desorbed concentration of pollutants in the marine waters, based on the above described equation, is presented in *Table 5.6k*.

Table 5.k - Desorbed Concentrations of Pollutants (mg L^{-1})

Parameter	Desorbed Concentration	Background Concentration	Total Concentration	Assessment Standard
Copper	0.35	2.51	2.86	5
Total PAHs	0.066	-	0.066	0.2
Total PCBs	0.00009	-	0.00009	0.014
TBT	0.00009	0.01	0.01009	0.002

5.6.48 The data in the above table predict that the concentrations of copper, PAHs and PCBs released to the marine waters due to desorbtion will not result in exceedances of the relevant assessment standards. There are therefore not predicted to be adverse impacts to water quality due to the release of these pollutants. The release of TBT to the water column from the sediment plumes is only predicted to increase background concentrations by less 0.1%, which is a negligible increase. The release from the sediment plumes is not therefore predicted to substantively increase the background concentrations, even with the extremely conservative assumption regarding the release of TBT to the surrounding waters. Furthermore, the fact that the increases will be temporary (ie for the duration of reclamation construction) means that the predicted impacts will not affect the long term recovery of the water body in future. The impact due to the release of TBT is therefore not considered to be an adverse impact.

YAM O

5.6.49 The assessment of the impacts on water quality parameters from the dredging at the Yam O reclamation is based on the previously calculated suspended sediment concentrations (see *Table 5.6i*) and the sediment quality data for the Yam O reclamation area. To assess decreases in dissolved oxygen concentrations it is assumed that all of the COD is utilised by the sediments in suspension. The release of ammonia and total nitrogen to the water column is calculated assuming these parameters are transported and diluted at the same rate as the

(51) Maunsell Consultants Asia Ltd (1995). *Op cit.*

sediment in suspension. A review of the routine EPD water quality monitoring data for Station NM1 has determined that unionised ammonia constitutes approximately 3.8% of the total ammonia concentrations and this value has therefore been used to convert the release of total ammonia to unionised ammonia. In order to compare the predicted increases in nitrogen to the water column with the WQO for total inorganic nitrogen it has been assumed, conservatively, that the release of total nitrogen can be used to represent total inorganic nitrogen. The results of the calculations of the effects of the dredging works on water quality are given in *Table 5.6l*.

Table 5.6l - Calculated Water Quality Impacts from Dredging at the Yam O Reclamation

Distance from Source (m)	SS (mg L^{-1})	DO Decrease (mg L^{-1})	Unionised Ammonia (mg L^{-1})	Total Nitrogen (mg L^{-1})
100	14.7	0.76	0.00004	0.016
200	7.3	0.38	0.00002	0.008
300	4.9	0.25	0.00001	0.005
400	3.7	0.19	<0.00001	0.004
500	2.9	0.15	<0.00001	0.003
600	2.4	0.13	<0.00001	0.003
700	2.1	0.11	<0.00001	0.002
800	1.8	0.10	<0.00001	0.002

5.6.50 The background dissolved oxygen concentration in the vicinity of the dredging for the Yam O reclamation has been defined as 4.6 mg L^{-1}. Therefore within 100 m of the dredging operations the WQO for dissolved oxygen of 4 mg L^{-1} is predicted to be breached. However, at 200 m from the dredging works compliance with the WQO is predicted to be achieved. There is therefore predicted to be a localised breach of the WQO for dissolved oxygen. This is not considered to be an adverse impact requiring mitigation as the area of WQO non-compliance is limited in extent and does not contain any sensitive receivers.

5.6.51 The background concentration of unionised ammonia in the vicinity of the Yam O reclamation is 0.005 mg L^{-1}, while the maximum predicted increase in unionised ammonia in the vicinity of the dredging works is 0.00002 mg L^{-1}. Therefore the predicted increase in unionised ammonia from the dredging works will not cause a breach of the WQO for unionised ammonia and is thus environmentally acceptable. The background concentration of total inorganic nitrogen is 0.43 mg L^{-1}. The maximum increase in total nitrogen (taken here to represent total inorganic nitrogen) in the vicinity of the dredging works is 0.016 mg L^{-1}, which would represent a 3.7% increase above the existing background and result in a total concentration of 0.0446 mg L^{-1}. It is therefore concluded that the predicted impacts to total inorganic nitrogen will be environmentally acceptable as the predicted elevations will not cause the WQO of 0.5 mg L^{-1} to be breached.

5.6.52 The release of pollutants to the water column has been calculated using the same approach as the Penny's Bay reclamation and using the suspended sediment concentrations calculated above. The results of the assessment of the release of pollutants are contained in *Table 5.6m*.

Table 5.6m - Calculated Water Quality Impacts from Dredging at the Yam O Reclamation

Distance from Source (m)	SS (mg L^{-1})	Copper (mg L^{-1})	Total PAHs (mg L^{-1})	Total PCBs (mg L^{-1})	TBT (mg L^{-1})
100	14.7	2.64	0.117	0.00009	0.0006
200	7.3	1.94	0.059	0.00009	0.0003
300	4.9	1.54	0.039	0.00008	0.0002
400	3.7	1.27	0.029	0.00008	0.0001
500	2.9	1.08	0.023	0.00007	0.0001
600	2.4	0.94	0.020	0.00007	<0.0001
700	2.1	0.84	0.017	0.00007	<0.0001
800	1.8	0.75	0.015	0.00006	<0.0001

5.6.53 The maximum predicted increases in copper concentrations in the vicinity of the dredging works is 2.64 μg L^{-1}, which would give a total copper concentration of 5.15 μg L^{-1}, which is slightly higher than the assessment standard of 5 μg L^{-1}. However, at 200m from the dredger the copper concentration is predicted to reduce to 1.94 μg L^{-1}, giving a total value of 4.45 μg L^{-1}. This value is below the level of concern of 5 μg L^{-1}. The predicted increases in copper concentrations are only predicted to result in a breach of the standard within 200 m of the dredger, which is localised impact to an area not containing any sensitive receivers. Therefore, the predicted impacts to water quality in terms of increases in copper concentrations would be environmentally acceptable.

5.6.54 The predicted increases in the concentrations of PAHs and PCBs are within the assessment standard values of 0.2 μg L^{-1} and 0.014 μg L^{-1} and as such are not predicted to cause adverse impacts to water quality. The maximum predicted increases in TBT concentrations in the vicinity of the dredger at Yam O is 0.0006 μg L^{-1}, which represents a 6.7% increase above background, while at 200m from the dredger the predicted releases of TBT represent a 3% increase above background. These are considered to be a small increases, despite the very conservative assessment of the release of TBT, and as such would not add significantly to the background. Also, the impacts to water quality would only persist during the dredging programme and as such the dredging works would not prevent the long term recovery of the water body. Therefore, the predicted increases in TBT concentrations are not predicted to be an adverse impact.

CUMULATIVE IMPACTS

5.6.55 There are a number of concurrent projects, which could give rise to cumulative impacts at sensitive receivers, as discussed in *Section 5.5.1*. A review of the sediment plume modelling for these concurrent projects has been undertaken to identify potential cumulative impacts at sensitive receivers. Only two of the sensitive receivers predicted to experience significant elevated suspended sediment concentrations from the formation of the Penny's Bay and Yam O reclamations are also expected to be impacted by sediment plumes from the identified concurrent projects as follows:

- Ma Wan Fish Culture Zone; and
- Tung Wan Beach (Ma Wan).

5.6.56 Cumulative impacts have therefore only been considered at these two sensitive receivers.

5.6.57 The calculation of the elevations in suspended sediment concentrations at the sensitive receivers from the dredging and filling for the reclamation at Penny's Bay found that the highest impacts at the sensitive receivers (see *Tables 5.6g* and *5.6h*) were generated during the dry season. A review of the previous studies for the concurrent projects determined that for the majority of those projects that the highest impacts at the above identified sensitive receivers were also predicted to occur in the dry season. The assessment of cumulative impacts to sensitive receivers has been carried out for this worst case condition from the impacts of the construction of the Theme Park reclamations at Penny's Bay and Yam O.

5.6.58 The results of the cumulative impact assessment are presented in *Table 5.6o* which contains predictions of the elevations in suspended sediment concentrations at the two identified sensitive receivers for the concurrent projects; the predicted increases in suspended sediment have been derived from specific sediment plume modelling studies conducted for the identified projects.

Table 5.6o - Maximum Predicted Cumulative Elevations in Suspended Sediment Concentrations (mg L^{-1}) at Sensitive Receivers

Project	**Sensitive Receiver**	
	Ma Wan FCZ (Allowable increase in concentration 4.5 mg L^{-1})	**Tung Wan Beach (Allowable increase in concentration 4.5 mg L^{-1})**
CT9 Reclamation	3.7	2.5
Backfilling North of Lantau and South Tsing Yi MBAs	3.0	7.0
Sand Winning at West Sulphur Channel	<1	<1
Sand Winning at East Lamma Channel	0.0	0.0
Sham Tseng Further Reclamation	1.5	2.1
Tsuen Wan Bay Further Reclamation	0.0	0.0
Tang Lung Chau Dangerous Goods Anchorage	0.9	2.7
HEC Lamma Extension Reclamation	0.0	0.0
Tung Chung & Tai Ho Further Development Reclamation	<1	<1
Disposal of Contaminated Mud at East Sha Chau CMPIV	0.0	0.0
Theme Park		
Penny's Bay Reclamation Maximum Dredging Maximum Filling	 2.7 4.2	 0.5 0.7
Yam O Reclamation	0.0	0.0
Total **Maximum Dredging** **Maximum Filling**	 **12.8** **14.3**	 **15.8** **16.0**

Notes :

1. Shaded cells indicate exceedances of the WQOs.
2. For sand winning at the West Sulphur Channel MBA and construction of the Tung Chung & Tai Ho Further Development Reclamation the computer modelling predicted that low concentration sediment plumes would impact the two sensitive receivers. However, tabulated values were not given and the only information was from contour plots where the lower interval was 1 mg L^{-1}. In calculating the total cumulative concentrations a value of 0.5 mg L^{-1} elevation at the sensitive receivers was assumed for these two projects.

5.6.59 The data in the above table predicts that the total cumulative impact of the above projects, including the Penny's Bay and Yam O reclamations, will lead to an exceedance of the WQO at Tung Wan Beach. The total predicted elevations are 15.8 mg L^{-1} and 16.0 mg L^{-1}, compared to an allowable elevation of 4.5 mg L^{-1}. The predicted contributions of the Penny's Bay reclamation to the total concentrations are 0.5 mg L^{-1} and 0.7 mg L, which is less than 5% of the total and alone does not breach the WQO. Specific constraints on the filling and dredging at the Theme Park reclamation at Penny's Bay will not reduce the predicted cumulative impact to below the WQO and it will thus be the responsibility of the concurrent projects to apply mitigation measures, should unacceptable impacts be detected during construction.

5.6.60 At the Ma Wan Fish Culture Zone exceedances of the WQO are predicted to occur due to the cumulative impacts of the above projects. The total cumulative increase in suspended sediment concentrations are predicted to be 12.8 mg L^{-1} and 14.3 mg L^{-1}, of which the construction of the Penny's Bay reclamation contributes 2.7 mg L^{-1} and 4.2 mg L^{-1} or approximately 21.1% and 29.4% respectively. It will therefore be necessary to consider the provision of mitigation measures to protect water quality at the Ma Wan Fish Culture Zone.

5.6.61 There is the potential for the suspended sediment plumes from the construction of the Penny's Bay reclamation to overlap with those from the construction of the Route 10 Toll Plaza, in the vicinity of the Fa Peng headland. However, such cumulative impacts may be prevented by ensuring that the seawalls along Section R6, R7 and the eastern side of Section R4 are constructed above the water level prior to the commencement of the construction of the Route 10 Toll Plaza. This should prevent any sediment plumes from the Penny's bay reclamation being transported over the Route 10 site on the flood tide and prevent any plumes from the Route 10 construction works being carried over the Penny's Bay reclamation site on the ebb tide.

Reclamation Phasing

5.6.62 The reclamation in Penny's Bay will be constructed progressively from west to east. This means that there will be no formation of embayed areas during the construction of the reclamation, as might have occurred if the reclamation was constructed in segments advancing from either side of reclamation area. There will therefore be no need to consider mitigation measures to prevent the formation of embayed areas, such as altering the phasing of the reclamation.

LAND BASED CONSTRUCTION ACTIVITIES

5.6.63 The potential sources of impacts, described in *Section 5.5.2*, may be readily controlled by appropriate on-site measures to minimise potential impacts and, as such, no further assessment of impacts has been carried out.

5.7 MITIGATION OF ENVIRONMENTAL IMPACTS - CONSTRUCTION PHASE

5.7.1 The description of mitigation measures to prevent adverse impacts to water quality during the construction phase has been divided into two aspects, formation of the reclamation and land based construction activities, including those for the Theme Park and for the road and rail links.

RECLAMATION FORMATION

5.7.2 Suitable mitigation measures to prevent adverse impacts to water quality during reclamation formation are discussed here for the Penny's Bay and Yam O reclamations. The implications of potential concurrent projects for the mitigation of dredging and filling at the reclamation site are also discussed.

Penny's Bay

5.7.3 Mitigation for the dredging and filling for the construction of the Theme Park reclamation at Penny's Bay will take two main forms, operation constraints and general plant working methods, which are both discussed below.

5.7.4 The impacts to water quality from the loss of sediment to suspension was assessed in terms of the maximum rates of dredging and filling during the construction of the Penny's Bay reclamation. The assessment was carried out based on the predicted loss rates of fine sediment to suspension from the different types of plant working on the site during the times of maximum dredging and filling. The highest loss rate was predicted to occur during the time at which the maximum rate of filling was occurring. The maximum loss rate was calculated to be 25.3 kg s^{-1} and it was predicted that this rate of loss would not give rise to adverse impacts. It is therefore recommended that the maximum loss rate during the construction of the reclamation be kept below this limit. In order to ensure compliance with this measure it will be necessary to calculate the loss rates during the construction of the reclamation for the plant operating at any one time. The calculation of the loss rate may be accomplished using the information given in *Table 5.7a*, which is based on the loss rates used in the above assessment.

Table 5.7a - Calculation of the Loss of Fine Sediment to Suspension

Plant Type/Operation	**Loss Rate (A)**	**Rate of Working in m^3 s^{-1} (B)**	**Loss Rate in kg s^{-1} = A x B**
Grab dredger	17 kg m^{-3} dredged		
Trailer dredger - dredging	7 kg m^{-3} dredged		
Trailer dredger - filling	9.33 kg m^{-3} filled		
Total	-	-	

Notes :

1. The rate of working is to be filled in and the loss rate calculated.
2. The total loss rate should be less than 25.3 kg s^{-1}

5.7.5 The calculated total loss rate in the above table should be less than 25.3 kg s^{-1}. If the calculated loss rate is greater than 25.3 kg s^{-1} then either the quantities of plant operating or the rates of working should be reduced.

5.7.6 The loss rate for dredging and filling by a trailing suction hopper dredger ('trailer') is assumed to be independent of the size of the dredger. It is assumed that the trailer will deliver their load of sand fill into the reclamation by bottom dumping. The loss rate is calculated based on a maximum fines content of the material delivered to site of 8%, which will be achievable event for high *in situ* fines content at the borrow area. The loss rate for grab dredging is based on the use of an 8.5 m^3 grab. Should larger grabs be used than the same loss rate may be applied, although the actual loss rate is likely to be lower. However, if the Contractor can demonstrate through the use of field trials that the actual loss rates from the proposed plant and operating methods are lower than those shown in *Table 5.7a* then the loss rate figures in the second column may be revised and the total loss rate re-calculated. The total calculated loss rate should still be less than 25.3 kg s^{-1}.

5.7.7 The above described limits on the rates of working to control loss of fine sediment will be sufficient to prevent adverse impacts to water quality during the construction of the reclamation. However, an additional measure would be to ensure that seawalls along the face of the reclamation are constructed early in the programme, which would serve to shelter the works area from tidal currents and hence minimise the transport of fine sediment in suspension away from the works area. Priority should be given to the seawall along the western frontage of the reclamation. A requirement is that the filling activities should be undertaken (ie discharge of sand fill from trailing suction hopper dredgers) behind seawalls or other similar structure to act as a barrier. The seawalls, or other suitable barrier, should be constructed at least 200 m in advance of the filling point.

5.7.8 The following general working methods shall be applied to supplement the operational constraints described above for dredging and filling to further minimise the loss of fine sediment to suspension.

- for dredging contaminated (Class C) sediments fully-enclosed (water tight) grabs should be used to minimise the loss of sediment during the raising of the loaded grabs through the water column;
- for dredging uncontaminated sediment tightly closing grabs should be used to restrict the loss of fine sediment to suspension;
- the descent speed of grabs should be controlled to minimise the seabed impact speed;
- barges should be loaded carefully to avoid splashing of material;
- all barges used for the transport of dredged materials should be fitted with tight bottom seals in order to prevent leakage of material during loading and transport;
- all barges should be filled to a level which ensures that material does not spill over during loading and transport to the disposal site and that adequate freeboard is maintained to ensure that the decks are not washed by wave action;
- the speed of trailer dredger should be controlled within the works area to prevent propeller wash from stirring up the sea bed sediments;
- when dredging mud at the reclamation site trailer dredgers should be prohibited from overflowing;
- the use of Lean Mixture Overboard (LMOB) will be permitted during the raising and lower of the suction head, but should cease once the suction head is in contact with the sea bed;
- “rainbowing” sand fill from trailer dredgers will not normally be permitted, except when the material is discharged onto areas above water level and are sheltered behind seawalls, or other suitable barriers, which have been constructed at least 200 m in advance of the discharge point; and
- the works shall cause no visible foam, oil, grease or litter or other objectionable matter to be present in the water within and adjacent to the reclamation site and along the route to and from the marine borrow area and disposal site.

5.7.9 There is planned to be cutter suction dredgers operating in a re-handling basin, the operation of which may cause fine sediment lost to be lost to suspension. It is recommended that a suitable device, such as a diffuser or similar, be fitted to the cutter suction dredger, which discharges the re-handled fill in thin layers. The design of the device should be such that the fill material does not disturb the sea bed and that a density flow is formed close to the sea bed. The location of the re-handling basin should be such that it is always positioned behind completed seawalls or other suitable barriers, which have been constructed at least 200 m in advance of the location of the re-handling basin. This measure will ensure that any fine sediment lost to suspension during the operation of the re-handling basin is retained within the filling area, ie behind the seawalls.

5.7.10 The implementation of the above described operational constraints and general working methods as mitigation measures will ensure that the potential water quality impacts associated with the construction of the reclamation for the Theme Park in Penny's Bay will be minimised to levels that are not predicted to cause unacceptable impacts to either sensitive receivers of the receiving waters.

Yam O

5.7.11 Mitigation for the dredging and filling for the construction of the Theme Park reclamation at Penny's Bay will take two main forms, operational constraints and general plant working methods, which are both discussed below.

5.7.12 The following operational constraints should be placed on the construction of the reclamation at Yam O for the Theme Park.

- dredging should be undertaken using a single grab dredging with a maximum rate of working of 2,000 m^3 day^{-1}; and
- filling should be undertaken behind seawalls which have been constructed above the water surface.

5.7.13 The above operational constraints will be sufficient to prevent adverse impacts to water quality. However, to supplement the operational constraints the same general methods of working described above for the Penny's Bay reclamation should also be applied to the Yam O reclamation.

Cumulative Impacts

5.7.14 The potential cumulative impacts to sensitive receivers arising from concurrent projects have been assessed. Exceedances of the WQO were predicted to occur at the Ma Wan Fish Culture Zone and Tung Wan Beach on Ma Wan. However, the contribution of the construction of the Theme Park reclamations to the adverse impacts at the Tung Wan Beach was considered to be negligible and it would therefore be the responsibility of other projects to employ mitigation measures. The construction of the Theme Park reclamation at Penny's Bay was predicted to contribute up to approximately 29% of the total predicted increase in suspended sediment concentrations at the Ma Wan Fish Culture Zone and it was recommended that the need for specific mitigation measures be considered.

5.7.15 The above described mitigation measures for filling operations (ie filling behind completed seawalls) will ensure that the loss of fine sediment to suspension during filling of the Penny's Bay and Yam O reclamation is minimised. In the calculation of the increase in suspended sediment concentrations from the dredging and filling at the Penny's Bay reclamation for the maximum rate of filling the losses from filling contributed 15.4 kg s^{-1} out of a total of 25.3 kg s^{-1} (see *Table 5.6f*), which is 60.9% of the total. With the reduction in losses from filling, the calculated increases in suspended sediment concentrations at the Ma Wan Fish Culture Zone due to the maximum rate of filling of the Penny's Bay reclamation will be reduced from 4.2 mg L^{-1} to 1.6 mg L^{-1}. For the maximum rate of dredging the losses from filling contributed 5.1 kg s^{-1} out of a total of 16.3 kg s^{-1} (see *Table 5.6e*), which is 31.3% of the total. The calculated impacts at the Ma Wan Fish Culture Zone due to the maximum rate of dredging will therefore reduce from 2.7 mg L^{-1} (see *Table 5.6g*) to 1.9 mg L^{-1} with the retention of the losses from filling. The total predicted increases in concentrations at the Ma Wan Fish Culture Zone will thus be reduced to 12.0 mg L^{-1} and 11.6 mg L^{-1}, to which the construction of the Penny's Bay reclamation contributes 15.8% and 13.8%. The contribution due to the construction of the Penny's Bay reclamation has thus been reduced as much as is practicable (ie to less than 2 mg L^{-1}) and does not contribute significantly to the total concentrations at this sensitive receiver. Any further reductions in the impacts at the Ma Wan Fish Culture Zone will thus fall to the other concurrent projects.

5.7.16 In order to determine whether the predicted potential exceedance of the WQO at the Ma Wan Fish Culture Zone will adversely affect the fish stocks and thus whether this exceedance would constitute an adverse impact it is necessary to calculate the total suspended sediment concentrations (ie ambient plus the predicted increase). In determining the ambient concentration the maximum recorded suspended sediment concentration for the last five years has been considered, which was 27.3 mg L^{-1} at EPD routine water quality monitoring Station WM4 in 1995 (52) . Station WM4 is used because it is the closest station to the Ma Wan Fish Culture Zone. The use of the maximum recorded concentrations ensures that a conservative assessment is carried out. The maximum calculated increase in suspended sediment concentrations from cumulative projects is 12.0 mg L^{-1}, as discussed above. The total suspended sediment at the Ma Wan Fish Culture Zone used in the assessment is thus 39.3 mg L^{-1}. The potential impacts to fish stocks are assessed in *Section 9*, which discusses impact to fisheries. In that section it is concluded that a total suspended sediment concentration of 39.3 mg L^{-1} would not cause adverse impacts to the fish stocks in the Ma Wan Fish Culture Zone.

5.7.17 It should be noted that in the assessment the contributions of other concurrent projects at the Ma Wan Fish Culture Zone were based on worst case scenarios for each of those projects (ie the concurrent projects were assumed to be operating at their highest allowable rates) and that the probability of each of those worst case scenarios operating concurrently is considered to be low. Furthermore, it has been assumed that the maximum predicted increases in concentrations at the Ma Wan Fish Culture Zone for each of the concurrent projects occur at the same time within the tidal cycle, which may not necessarily be the case. For instance the impacts due to the disposal at North of Lantau, the Sham Tseng Further Reclamation and the CT9 construction works are likely to occur during the ebb phase of the tidal cycle, while the impacts from the construction of the Penny's Bay reclamation are most likely to occur on the flood tide. It may thus be concluded that the cumulative impacts assessed here are very much worst case and that the actual impacts are likely to be very much lower. As such there will be a low probability of the exceedance of the WQO at the Ma Wan Fish Culture Zone due to the impacts from the construction of the Theme Park reclamation at Penny's Bay in combination with other projects.

5.7.18 The predicted cumulative exceedance of the WQO will only occur when the maximum rates of working are being employed at each of the concurrent projects and at certain stages of the tidal cycle. This means that the duration of the exceedances will be limited, both in terms of the number of days upon which an exceedance could be recorded and the duration of the exceedance once recorded within a day. The maximum contribution of the construction of the reclamations for the Theme Park to the elevated suspended sediment concentrations at the Ma Wan Fish Culture Zone will only occur during periods of high rates of dredging,

(52) EPD (1996). Marine Water Quality in Hong Kong for 1995.

which occur in the early parts of the reclamation formation within the first year of construction. The sediment plumes from the dredging activity would only be expected to impact the Ma Wan Fish Culture Zone on the flood phase of the tidal cycle, causing short duration ‘spikes’ in the suspended sediment concentrations. The duration of these spikes is likely to be less than 2 hours during each tidal cycle.

5.7.19 As there will be multiple projects occurring in areas in the vicinity of the Theme Park it has been recommended in the Environmental Monitoring and Audit (EM&A) Manual that an Environmental Projects Office (ENPO) be set up for the Project. The responsibility for employing further mitigation measures and the implementation of such measures for the above discussed sensitive receivers would be determined through the ENPO. This will ensure that there are no adverse impacts at the above discussed sensitive receivers.

5.7.20 In order to prevent cumulative impacts with the concurrent construction of the Route 10 Toll Plaza the seawalls along the eastern side of the Phase II reclamation (see *Figure 5.6b*) should be constructed to above the water surface prior to the commencement of the works for the Route 10 Toll Plaza.

LAND BASED CONSTRUCTION ACTIVITIES

5.7.21 In this section appropriate on-site measures are defined to minimise potential impacts, which will be sufficient to prevent adverse impacts to water quality from land based construction activities, including those for the Theme Park and for the road and rail links. These measures are appropriate for general land based construction activities. However, specific measures associated with the Penny’s Bay Rail Link (PBRL) are detailed in *Annex M*, which contains the EIA for the PBRL.

Surface Run-off

5.7.22 Surface run-off from the Theme Park construction site should be directed into storm drains via adequately designed sand/silt removal facilities such as sand traps, silt traps and sediment basins. Channels, earth bunds or sand bag barriers should be provided on site to properly direct stormwater to such silt removal facilities. Catchpits and perimeter channels should be constructed in advance of site formation works and earthworks.

5.7.23 Silt removal facilities, channels and manholes should be maintained and the deposited silt and grit should be removed regularly, at the onset of and after each rainstorm to ensure that these facilities are functioning properly at all times.

5.7.24 If excavation cannot be avoided during rainy seasons, temporarily exposed soil surfaces should be covered e.g. by tarpaulin, and temporary access roads should be protected by crushed stone or gravel, as excavation proceeds. Intercepting channels should be provided (e.g. along the crest/edge of the excavation) to prevent storm runoff from washing across exposed soil surfaces. Arrangements should always be in place to ensure that adequate surface protection measures can be safely carried out well before the arrival of a rainstorm.

5.7.25 Earthworks final surfaces should be well compacted and the subsequent permanent work or surface protection should be carried out as soon as practical after the final surfaces are formed to prevent erosion caused by rainstorms. Appropriate intercepting channels should be provided where necessary. Rainwater pumped out from trenches or foundation excavations should be discharged into storm drains via silt removal facilities.

5.7.26 Open stockpiles of construction materials (e.g. aggregates and sand) on site should be covered with tarpaulin or similar fabric during rainstorms. Measures should be taken to prevent the washing away of construction materials, soil, silt or debris into any drainage system.

5.7.27 Manholes (including any newly constructed ones) should always be adequately covered and temporarily sealed so as to prevent silt, construction materials or debris from getting into the drainage system, and to prevent storm run-off from getting into foul sewers. Discharges of surface run-off into foul sewers must always be prevented in order not to unduly overload the foul sewerage system.

Excavation for the Artificial Lake

5.7.28 The sediments to be excavated for construction of the artificial lake have been found to be contaminated with products associated with the shipyard in Penny's Bay. The above described measures for controlling run-off from the construction site will be sufficient to prevent any contaminated sediments from being carried into the stormwater drains and discharged to marine waters. Any particular measures for handling and disposal of these sediments are described in *Section 6*, which assesses waste management.

Groundwater

5.7.29 Groundwater pumped out of wells, etc. for the lowering of ground water level in foundation construction, such as that required for new buildings, should be discharged into storm drains after being passed through appropriate silt removal facilities.

Wheel Washing Water

5.7.30 All vehicles and plant should be cleaned before they leave the construction site to ensure that no earth, mud or debris is deposited by them on roads. A wheel washing bay should be provided at every site exit, if practicable, and wash-water should have sand and silt settled out or removed before being discharged into the storm drains. The section of construction road between the wheel washing bay and the public road should be paved with backfall to reduce vehicle tracking of soil and to prevent site run-off from entering public road drains.

Wastewater from Building Construction

5.7.31 Wastewater generated from concreting, plastering, internal decoration, cleaning work and other similar activities, should undergo large object removal by installing bar traps at the drain inlets. It is not considered necessary to carry out silt removal due to the small quantities of water involved. Similarly, pH adjustment of such water is not considered necessary due to the small quantities and the fact that the water is only likely to be mildly alkaline.

Wastewater from Site Facilities

5.7.32 Sewage from toilets, kitchens and similar facilities should be discharged into a foul sewer or chemical toilets should be provided. Should the use of chemical toilets be necessary then these should be provided by a licensed contractor, who will be responsible for appropriate disposal and maintenance of these facilities. Wastewater collected from canteen kitchens, including that from basins, sinks and floor drains, should be discharged into foul sewers via grease traps.

5.7.33 Vehicle and plant servicing areas, vehicle wash bays and lubrication bays should, as far as possible, be located within roofed areas. The drainage in these covered areas should be connected to foul sewers via a petrol interceptor. Oil leakage or spillage should be contained and cleaned up immediately. Waste oil should be collected and stored for recycling or disposal, in accordance with the *Waste Disposal Ordinance*.

Storage and Handling of Oil, Other Petroleum Products and Chemicals

5.7.34 All fuel tanks and chemical storage areas should be provided with locks and be sited on sealed areas. The storage areas should be surrounded by bunds with a capacity equal to 110% of the storage capacity of the largest tank to prevent spilled oil, fuel and chemicals from reaching the receiving waters. The Contractors should prepare guidelines and procedures for immediate clean-up actions following any spillages of oil, fuel or chemicals. Surface run-off from bunded areas should pass through oil/grease traps prior to discharge to the stormwater system.

5.8 ASSESSMENT METHODOLOGY - OPERATION

5.8.1 The assessment of the impacts to water quality from the operation of the Theme Park is split into four main aspects.

- The surrounding marine waters;
- The artificial lake;
- The adequacy of the sewerage system, including the Siu Ho Wan Sewage Treatment Works (STW); and
- The road and rail links.

MARINE WATERS

5.8.2 The operation of the Theme Park will have the potential to affect the water quality of the surrounding marine waters in two ways, by changing the hydrodynamics and through the discharges of pollutants from the Theme Park. The impacts to hydrodynamics and the discharge of sewage effluents and stormwater from the Theme Park have been assessed through computational modelling. The impacts from the potential discharge of toxic substances (residual chlorine, pesticides and herbicides) have been assessed qualitatively.

Hydrodynamics

5.8.3 The formation of the reclamations for the Theme Park at Penny’s Bay and Yam O have the potential to affect tidal current patterns and tidal discharges, which could affect water quality over a wide area and local sediment erosion/deposition patterns in the vicinity of the reclamations. In order to assess the effects of the reclamations on tidal current patterns and discharges computational hydraulic modelling has been undertaken using the Delft 3D-FLOW hydrodynamic model. This model calculates flow and transport phenomena resulting from tidal and meteorological forcing by solving the unsteady shallow water equations of continuity and momentum. The main application of Delft3D-FLOW is the three-dimensional simulation of tidal and wind driven flows, including the effect of density differences due to non-uniform temperature and salinity distributions in shallow seas, coastal areas, estuaries, rivers and lakes. The model aims to simulate flow phenomena where the horizontal length scales are significantly larger then the vertical scales. This model is , therefore, suited to simulating the complex hydrodynamic conditions in the Hong Kong SAR waters and the Pearl River estuary.

5.8.4 The hydrodynamic modelling for this Study was based on the model which was originally set up, calibrated and validated for the Hong Kong SAR Government [(53)]. This model, known as the Upgrade Model, covers the whole of the Hong Kong SAR waters, the Pearl River estuary, Mirs Bay, the Lema Channel and stretches of the South China coastline to the west of Macau and to the east of Mirs Bay. This model has recently been updated using an extensive new field data set [(54)] , which has resulted in an improved representation of the hydraulics of the Hong Kong SAR waters.

5.8.5 The grid of the updated model was refined in the vicinity of the reclamations at Penny's Bay and Yam O to provide an improved representation of the features of the reclamations. The overall model grid is shown in *Figure 5.8a* and the detail of the model grid around Lantau Island is shown in *Figure 5.8b*. The hydrodynamic model has been used to simulate two scenarios, which are defined below. Each of the scenarios was simulated for 15 day spring-neap tidal cycles in the wet and dry seasons.

- Baseline, corresponding to all planned reclamations in 2012; and
- Completed, including the reclamations at Penny's Bay and Yam O.

5.8.6 The reclamations in the Baseline Scenario were defined with reference to those adopted for the study *Update on Cumulative Water Quality and Hydrological Effect of Coastal Development and Upgrading of Assessment Tool* [(55)] . Major future reclamations and developments, which are included in the baseline are as follows.

- Tuen Mun Port;
- Tung Chung and Tai Ho reclamations;
- Siu Lam Typhoon Shelter;
- Tang Lung Chau Dangerous Goods Anchorage;
- Container Terminal 9;
- Tsuen Wan Bay Further Reclamation, including the reclamation for the KCRC West Rail;
- Sham Tseng Further Reclamation;
- Peng Chau Typhoon Shelter;
- Kowloon Point Reclamation;
- Green Island Reclamation;
- Central-Wanchai reclamations;
- South East Kowloon Reclamation;
- Tseung Kwan O reclamations;
- Hongkong Electric Lamma Extension on western Lamma Island; and
- The bridges for Crosslinks and Route 10.

5.8.7 Based on the most recently available information the following modifications were made to the reclamations and developments included in the study *Update on Cumulative Water Quality and Hydrological Effect of Coastal Development and Upgrading of Assessment Tool*.

(53) Delft Hydraulics (1998). Upgrading of the Water Quality and Hydraulic Mathematical Models. Final Model Calibration and Validation Report; Part 2, Hydraulic Validation and WQ Calibration.

(54) Hyder Environmental (1999). Update on Cumulative Water Quality and Hydrological Effect of Coastal Developments and Upgrading of Assessment, Calibration and Verification of the Hydrodynamic Model.

(55) Hyder Environmental (1999). *Op cit*.

- The layouts of the Tseung Kwan O reclamations were modified to account for a revised Area 131 and an extension of reclamations up to the cross bay bridge;
- The island reclamation in Tung Chung Bay was deleted;
- The layout of the South East Kowloon reclamation was reduced to account for the new planning proposals for the area;
- A reclamation was introduced on the western side of Lamma Island for a proposed Waste to Energy Incineration Facility; and
- The West Lamma Breakwater was deleted from the Baseline scenario, which would only be necessary once any proposed container terminals were constructed in the vicinity of Kau Yi Chau.

5.8.8 The layouts for the Penny's Bay and Yam O reclamations were defined as part of this Study.

Water Quality

5.8.9 During the operation of the Theme Park discharges of waste water will occur in the form of sewage effluents and storm water. The sewage effluent will be transported to the Siu Ho Wan Sewage Treatment Works (STW) for treatment and subsequent disposal to the marine waters via a submarine outfall, which discharges to the south east of the Brothers islands. Storm water will be discharged to the marine waters to the south and east of the Theme Park reclamation at Penny's Bay via a number of culverts. Both of these discharges will increase the pollutant loads to the receiving marine waters and have the potential to cause adverse impacts to water quality. Also, the changes in hydrodynamics associated with the formation of the reclamation may have the potential to affect water quality.

5.8.10 In order to study the above described impacts computational modelling has been carried out using the Delft3D-WAQ water quality model. The model simulates water quality processes in three dimensions. The model includes such parameters as dissolved oxygen, bacteria, nutrients, phytoplankton and suspended sediments. Physical processes, such as the exchange of oxygen with the atmosphere and the setting of suspended substances, are included. Biochemical processes simulated in the model include nitrification, algal growth and decay and the decay of organic matter, which affect dissolved oxygen concentrations. Hydrodynamic data for the water quality model is provided by the Delft3D-Flow hydrodynamic model.

5.8.11 The water quality model used in this Study is based on the model which was originally set up, calibrated and validated for the Hong Kong SAR Government [(56)]. This model has the same coverage as the hydrodynamic model, which includes the whole of the Hong Kong SAR marine waters, the Pearl River estuary, Mirs Bay and the Lema Channel. Like the hydrodynamic model, the water quality model has recently been updated during the study *Update on Cumulative Water Quality and Hydrological Effect of Coastal Developments and Upgrading of Assessment Tool*.

5.8.12 The water quality model uses the grid of the hydrodynamic model as a basis, as shown in *Figures 5.8a* and *5.8b*, but in order to make the simulations more efficient the grid is aggregated by a factor of 2 in the horizontal plane for the areas remote from the Theme Park reclamation. In the vicinity of the Theme Park reclamations the hydrodynamic grid remains

(56) Delft Hydraulics (1998). *Op cit*.

unaggregated so that the a good representation of the reclamations is achieved. The grid for the water quality model is shown in *Figure 5.8c*. In the vertical there is an aggregation of the ten layers used in the hydrodynamic model to five layers with relative thicknesses of 10%-20%-20%-30%-20% of the water depth from the surface to the bed.

5.8.13 The water quality model has been used to simulate a complete year so that long term temporal variations in various water quality parameters may be determined. Input hydrodynamic data has been provided by aggregating the results from the Delft 3D-Flow model for the 15 day spring-neap tidal cycles in the wet and dry seasons.

5.8.14 The water quality model has been used to simulate two scenarios, as follows.

- Baseline, corresponding to all pollutant discharges in 2012; and
- Completed, including the discharges from the Theme Park reclamations.

5.8.15 A comparison between the two scenarios will enable the effects of the operation of the Theme Park on water quality to be determined.

5.8.16 During operation of the Theme Park there are proposed to be nightly fireworks displays. The majority of the residue from the spent fireworks is likely to fall onto the Theme Park and may then be transported to the surrounding marine waters. The assessment has focussed devising measures to prevent adverse impacts to water quality from the discharge of fireworks residue.

Uncertainties in Assessment Methodology

5.8.17 Quantitative uncertainties in the hydrodynamic and water quality modelling should be considered when making an evaluation of the modelling predictions. For the hydrodynamic modelling these are considered to be negligible for the following reasons.

- The computational grid is sufficiently refined to provide representative simulations results;
- The model has been calibrated and validated to provide reliable predictions of hydrodynamics in the areas affected by the Theme Park reclamations; and
- The simulations comprise a sufficient spin up period of 8 days so that the initial conditions do not affect the results.

5.8.18 For the water quality modelling realistic worst case assumptions were made in deriving the input data for the model in order to provide conservative predictions of impacts. It is therefore possible that the input data for the relevant parameters may cause an overestimation of the water quality impacts. Some examples of the conservative nature of the input parameters are given below.

- The upper bound estimates were used for the sewage effluent flows and pollutant concentrations from the Theme Park and from other developments on Lantau Island; and
- The background pollutant loads have been derived from conservative population estimates, and may therefore over-predict the loads.

Toxic Substances

5.8.19 The operators of the Theme Park propose to use sodium hypochlorite to disinfect any waters used on attractions within the park. Sodium hypochlorite produces residual chlorine, which is a toxic substance and leads to the production of toxic by-products. The discharge of water containing high concentrations of residual chlorine and its by-products to marine waters should be avoided so as to prevent the build-up of such a toxic substance to a level at which harmful effects on marine organisms could occur. The assessment focuses on determining suitable measures to prevent the discharge of residual chlorine and its by-products.

5.8.20 It is likely that both pesticides and herbicides will be used on the landscaped areas of the Theme Park. As for residual chlorine, these substances are toxic and the discharge of such substances in significant quantities to the marine environment should be prevented. The assessment focuses on deriving suitable measures to prevent the discharge of pesticides and herbicides to the marine environment.

Territory Wide Assessment

5.8.21 The hydrodynamic and water quality models cover the whole of Hong Kong waters, the Pearl River, Mirs Bay and the Lema Channel and as such are able to predict far field effects of the Theme Park on hydrodynamics and water quality. However, such wide ranging effects to water quality are unlikely and the assessment has focussed on the areas most likely to be affected, as shown on *Figure 5.3a*.

ARTIFICIAL LAKE

5.8.22 The artificial lake will serve three purposes as follows :

- providing a water recreation area;
- providing an aesthetically pleasing environment; and
- providing a source of irrigation water for the Theme Park.

5.8.23 The assessment of water quality within the lake makes use of the above defined beneficial uses to determine acceptable water quality within the lake. The water quality within the lake has been examined by considering the potential sources of water and the quality of that water. It is envisaged that during the wet season stormwater run-off will be used to maintain the water level, while during periods of low rainfall in the dry season the water will be ‘topped-up’ with water from an external source. Suitable mitigation measures have been defined to maintain water quality within the lake so that beneficial uses of the lake will not be compromised.

SEWERAGE SYSTEM

5.8.24 The sewerage system is assessed in terms of three aspects, the adequacy sewerage pipes to carry sewage effluent from the Theme Park to the Siu Ho Wan STW, the capacity of the Siu Ho Wan Sewage Treatment Works (STW) and the potential for failure/emergency shut down of the sewerage system.

5.8.25 The adequacy of the sewerage pipes has been assessed by comparing the design capacity of the pipes with expected sewage effluent flows generated by the Theme Park. The sewage effluent flows for various stages of the Theme Park development have been provided by the operator, based on experience with similar facilities in other parts of the world.

5.8.26 The Siu Ho Wan STW is currently receiving effluent flows from the Hong Kong International Airport at Chek Lap Kok and from the Tung Chung New Town. In the future the STW will receive increased flows from these two areas as a result of the expansion of the airport and from the increased residential developments in Tung Chung and Tai Ho. It is also proposed to transport the sewage flows from Discovery Bay to the STW, as well as, ultimately, the flows from Mui Wo on the southern side of Lantau Island. An upgrade to the Siu Ho Wan STW is currently being designed to cater for these increased flows. Originally the design had been carried out assuming that sewage effluents from the potential Container Terminals 10 and 11 in Penny's Bay and from Peng Chau would be carried to the STW. However, the planned Container Terminals 10 and 11 have now been replaced by the Theme Park development and it is no longer planned to connect Peng Chau to the STW. It will be necessary to determine whether the changes in the land use in Penny's Bay will result in the sewage flows to the Siu Ho Wan STW exceeding the design capacity. Both the flows from the initial phases of the Theme Park and the ultimate development are considered using sewage effluent flows provided by the Theme Park operator.

5.8.27 Either the failure of the sewerage system or the emergency shut down of the system will result in the discharge of untreated sewage effluent to the marine waters surrounding the Theme Park. The potential for such discharges is considered and suitable measures have been devised to minimise the risk of such occurrences and reduce the duration of these discharges should they occur.

ROAD AND RAIL LINKS

5.8.28 The operational design of the road and rail links have been reviewed to determine where there may be the potential for impacts to water quality to occur and suitable measures devised to mitigate the potential impacts.

5.9 IDENTIFICATION OF ENVIRONMENTAL IMPACTS - OPERATION

5.9.1 The identification of potential impacts to water quality from the operation of the Theme Park is split into four main aspects.

- The surrounding marine waters;
- The artificial lake;
- The adequacy of the sewerage system, including the Siu Ho Wan Sewage Treatment Works (STW); and
- Road and rail links.

MARINE WATERS

5.9.2 The operation of the Theme Park will have the potential to affect the water quality of the surrounding marine waters in two ways, by changing the hydrodynamics and through the discharges of pollutants from the Theme Park.

Hydrodynamics

5.9.3 Impacts to the hydrodynamic regime of the waters surrounding the Theme Park reclamations may be caused by the presence of the reclamations altering tidal currents. These changes may be in the form of increased current speeds in some areas and decreased speeds in others. Impacts may also occur to the discharge rates in the region surrounding the reclamations, which include the flow channel into and out of the Western Harbour and Victoria Harbour.

Any changes in tidal discharge would be important as they would indicate changes in the flushing capacity of the region, which could in turn affect water quality. An indicator of the effects on water quality of any changes to flushing capacity is salinity, which effectively acts as a conservative tracer and changes in concentration of salinity could be represent of changes in other water quality parameters. A cause for concern in terms of changes to flushing would be the areas to the west of the Penny's Bay reclamation, including Discovery bay and Sze Pak Wan, becoming poorly flushed because of a sheltering effect of the reclamation and thus leading to a deterioration in water quality. Such an impact would be undesirable due to the recreational uses of this area.

5.9.4 In order to address the above described potential impacts the following analyses have been carried out.

- Calculation of instantaneous, residual and average discharges through major flow channels;
- Presentation of tidal current vectors; and
- Presentation of contours of salinity.

5.9.5 The model results have been processed to calculated residual and average flood and ebb discharges through major flow channels for each of the wet and dry season simulations. The locations of the flow channels are shown on *Figure 5.9a* and have been selected to represent the flows into and out the areas where the Theme Park reclamations at Penny's Bay and Yam O may affect global hydrodynamics. At these same cross section graphs of instantaneous and accumulated discharges have been plotted for each of the wet and dry seasons. A comparison of the discharges for the Baseline and Completed Scenarios determines the effects of the reclamations on tidal discharges. This is an important factor as the rate at which pollutants are transported out of a particular body of water is related to the discharge rate.

5.9.6 Tidal current vectors have been plotted for each of the scenarios to determine the effects of the reclamations on tidal current speeds and directions. The vectors have been plotted for two instances during the tidal cycle, a falling (ebb) tide and a rising (flood) tide. The vectors have been produced for a spring tide only because the current speeds will be higher than those on a neap tide and any changes in speed and direction will therefore be most noticeable. For the wet season spring tide the vectors have been produced for the surface and bed layers as the wet season stratification results in differences in current speeds and directions between the surface and bed. In addition, contours of salinity are included on the wet season vector plots. The vectors for the dry season spring tide have been produced for the surface only as the waters are well mixed and there is little vertical difference in the tidal currents. No contours of salinity have been produced for the dry season tide as there is not expected to be significant spatial or vertical variations in salinity.

Water Quality

5.9.7 During the operational phase of the Theme Park sewage effluents from the Theme Park will be collected and transported to the Siu Ho Wan Sewage Treatment works via sub-surface sewerage pipelines. The effluents will be treated at the Siu Ho Wan STW and discharged to the marine waters to the north of the STW via a submarine outfall. In the future, during the operation of the Theme Park, the Siu Ho Wan STW will treat also effluents from the Chek Lap Kok airport, the Tung Chung and Tai Ho developments and Discovery Bay. The increase in the treated effluent flows and loads from the Siu Ho Wan STW as a result of the sewage generated by the Theme Park will have the potential to cause adverse impacts to water quality. Stormwater run-off from the Theme Park developments areas will be discharged to the marine waters to the south and east of the Theme Park at Penny's Bay via culverts. The stormwater may contain contaminants, which would have the potential to cause adverse impacts to water quality, most likely in the immediate vicinity of the discharge points due to the relatively low flow rates from these culverts. In order to determine the impacts on water quality from the increased discharges treated sewage effluents and storm water detailed water quality modelling has been carried out for two scenarios, Baseline and Completed.

5.9.8 The pollution loads for the baseline scenario, including sewage effluents and storm water discharges were derived from the pollution load inventory produced as part of the study *Update on Cumulative Water Quality and Hydrological Effect of Coastal Developments and Upgrading of Assessment Tool*. This data was used because it provides the most up to date information on pollution loads to the whole of the Hong Kong SAR marine waters and the Pearl River Estuary. The key features of the pollution load inventory, which affect the water quality in the vicinity of the Theme Park reclamations are the assumptions that the Peng Chau STW continues to discharge off Tai Lei and that the Strategic Sewage Disposal Scheme Phases I-IV, including the long sea outfall, have been implemented. Should adverse impacts to water quality be found to be occurring to the south of the Theme Park, which are attributable to the continued discharge of treated sewage effluents from the Peng Chau STW, then it may be necessary to consider devising alternate discharge locations for the treated sewage effluent.

5.9.9 As part of this Study the flows and loads from the Siu Ho Wan STW have been examined and modified to better reflect the expected conditions in 2012 without the additional flows from the Theme Park. At this time the Siu Ho Wan STW is expected to be receiving flows from the Chek Lap Kok airport, the Tung Chung and Tai Ho developments and Discovery Bay. Data on the influent flows and quality from the Chek Lap Kok airport and the Tung Chung and Tai Ho developments have been obtained from the *Final Design Memorandum* for the Siu Ho Wan STW. The influent flows and loads from Discovery Bay have been estimated assuming a population of 25,000 (57) , which is the expected ultimate development for the area and are based on the unit flow factors for domestic sewage in the Drainage Services Department *Sewerage Design Manual* (58). The treated effluent quality from the Siu Ho Wan STW has been calculated assuming a removal efficiencies of 70% for suspended solids and 55% for biochemical oxygen demand and a discharge concentration of *E. coli* of 20,000 cfu $100mL^{-1}$ (59). The influent flows and loads to the Siu Ho Wan STW for the Baseline scenario are shown in *Table 5.9a* and the resulting treated effluent flows and loads are shown in *Table 5.9b*.

(57) Communication with the Planning Department of the HKSAR Government.

(58) Drainage Services Department. Sewerage Manual.

(59) Communication with the Sewage Infrastructure Group of the Environmental Protection Department of the HKSAR Government

Table 5.9a - Influent Flows and Loads to the Siu Ho Wan STW for the Baseline Scenario

Parameter	Flow	SS	BOD	COD	TKN	NH3-N	TTM	E.coli
Source	**(m3 day^{-1})**	**(kg day^{-1})**	**(kg day^{-1})**	**(kg day^{-1})**	**(kg day^{-1})**	**(kg day^{-1})**	**(kg day^{-1})**	**(cfu day^{-1})**
Airport	16,596	4,979	4,979	10,757	769.0	429.0	31.0	3.3E+15
Tung Chung/Tai Ho	130,860	25,877	31,877	68,871	4,920.0	2,751.0	201.0	2.04E+16
Discovery Bay	9,250	1,000	1,050	2,250	212.5	125.0	14.8	1.08E+15
Total	156,706	31,856	37,906	81,878	5,901.5	3,305.0	246.8	2.48E+16

Table 5.9b - Treated Effluent Quality from the Siu Ho Wan STW for the Baseline Scenario

Parameter	Flow	SS	BOD	COD	TKN	NH3-N	TTM	E.coli
	(m3 day^{-1})	**(mg L^{-1})**	**(mg L^{-1})**	**(mg L^{-1})**	**(mg L^{-1})**	**(mg L^{-1})**	**(mg L^{-1})**	**(cfu 100mL^{-1})**
Effluent Quality	156,706	60.99	108.85	522.49	37.66	21.09	1.57	20,000

5.9.10 Data on the expected sewage flows from the Theme Park developments, including visitors to the Theme Park and other recreational facilities, hotel guests and employees, were provided by the Theme Park operator. The expected average daily flows have been split into a number of stages of development as follows.

- Theme Park opening day (2005) - 2,706 m^3 day^{-1};
- Theme Park Phase 1 Build out (2014) - 5,593 m^3 day^{-1}; and
- Theme Park Phase 2 completion (2024) - 12,140 m^3 day^{-1}.

5.9.11 The Theme Park Phase 2 completion flows have been used in the water quality modelling, so that the worst case sewage flows from the Theme Park may be considered. Should the results of the water quality modelling be acceptable then it would be concluded that the interim phases of the Theme Park would also considered to be acceptable in terms of water quality impacts.

5.9.12 The Theme Park operator also provided data on the expected quality of the sewage effluents generated by the Theme Park, which are as follows.

- Suspended Solids - 120 to 250 mg L^{-1};
- Chemical Oxygen Demand - 500 to 600 mg L^{-1};
- Biochemical Oxygen Demand - 250 to 450 mg L^{-1};
- Total Kjeldahl Nitrogen - 28 to 32 mg L^{-1}; and
- Ammoniacal Nitrogen - 24 to 26 mg L^{-1}.

5.9.13 In order to ensure that the water quality modelling is suitably conservative the upper bound concentrations for each of the above pollutants have been used to determine the input data for the water quality modelling. No data, however, were provided for Total Toxic Metals (TTM) and *E. coli*. In order to estimate the loads for these parameters worst case factors were derived from the data contained in *Table 5.9a* and applied to the flows from the Theme Park. It should be noted that the lack of data on *E. coli* is not critical because it is assumed that the Siu Ho Wan STW will still be able to meet the discharge standard of 20,000 cfu $100mL^{-1}$ with the additional flows from the Theme Park. The influent flows and loads to the Siu Ho Wan STW for the Completed scenario are shown in *Table 5.9c* and the resulting treated effluent flows and loads are shown in *Table 5.9d*.

Table 5.9c - Influent Flows and Loads to the Siu Ho Wan STW for the Completed Scenario

Parameter	Flow	SS	BOD	COD	TKN	NH3-N	TTM	E.coli
Source	**(m3 day^{-1})**	**(kg day^{-1})**	**(kg day^{-1})**	**(kg day^{-1})**	**(kg day^{-1})**	**(kg day^{-1})**	**(kg day^{-1})**	**(cfu day^{-1})**
Airport	16,596	4,979	4,979	10,757	769.0	429.0	31.0	3.30E+15
Tung Chung/Tai Ho	130,860	25,877	31,877	68,871	4,920.0	2,751.0	201.0	2.04E+16
Discovery Bay	9,250	1,000	1,050	2,250	212.5	125.0	14.8	1.08E+15
Theme Park	12,140	3,035	5,463	7,284	388.5	315.6	77.3	4.48E+15
Total	168,846	34,891	43,369	89,162	6,290.0	3,620.6	324.1	2.94E+16

Table 5.9d - Treated Effluent Quality from the Siu Ho Wan STW for the Completed Scenario

Parameter	Flow	SS	BOD	COD	TKN	NH3-N	TTM	E.coli
	(m3 day^{-1})	**(mg L^{-1})**	**(mg L^{-1})**	**(mg L^{-1})**	**(mg L^{-1})**	**(mg L^{-1})**	**(mg L^{-1})**	**(cfu 100mL^{-1})**
Effluent Quality	168,846	61.99	115.58	528.07	37.25	21.44	1.92	20,000

5.9.14 In addition to the sewage effluents generated by the Theme Park storm water discharges have also been included in the water quality modelling. The Theme Park at Penny's Bay has been divided into two main areas, the Theme Park and the commercial/developed areas behind the Theme Park. Based on an annual average rainfall of 1,756 mm at Discovery Bay the annual average flows rates from the Theme Park and commercial/developed areas has been calculated to be 2,907,930 m3 and 2,778,700 m3 respectively [(60)] and is based on a run-off factor of 0.92 (ie 8% loss in run-off). Rainfall data for Discovery Bay from the period 1980 to 1997 was analysed to determine the proportions of rainfall for the wet and dry seasons. For the purposes of the assessment the wet season was assumed to extend from April to September and the dry season from October to March. The analysis determined that, on average, 83.6% of the rainfall occurs in the wet season and 16.4% in the dry season.

5.9.15 The run-off from these areas are proposed to be discharged to marine waters via three culverts, two for the Theme Park and one for the commercial/developed areas. The locations of these outfalls are shown in Figure 5.9b, which show Outfalls 1 and 2 serving Phases 1 and 2 of the Theme Park respectively and Outfall 3 serving the commercial/developed areas. The catchment area for Outfall 1 is 99 ha and the catchment area for Outfall 2 is 81 ha. The average wet and dry season flows for the Theme Park were split according these areas. The resulting average wet and dry season storm water flows are shown in *Table 5.9e*.

Table 5.9e - Average Wet and Dry Season Stormwater Flows

Area	**Flow ($m^3 s^{-1}$)**	
	Wet Season	**Dry Season**
Theme Park		
Outfall 1	0.0848	0.0166
Outfall 2	0.0694	0.0136
Commercial/Developed Areas		
Outfall 3	0.1473	0.0289

5.9.16 Data on the pollutants in the stormwater were obtained from the Theme Park operator and were based on measurements made at a similar facility in Florida. The data can be considered to be representative for the proposed Theme Park at Penny's Bay and was used as input data for the water quality modelling. The pollutant concentrations are presented in *Table 5.9f*.

Table 5.9f - Pollutant Concentrations in the Stormwater from the Theme Park

Parameter	**Concentration**
Suspended Solids (mg L^{-1})	<50
Biochemical Oxygen Demand (mg L^{-1})	<50
Chemical Oxygen Demand (mg L^{-1})	<75
Total Phosphorous (mg L^{-1})	0.05 - 0.5
Total Nitrogen (mg L^{-1})	1 - 3
E. coli (cfu 100mL^{-1})	<100
Total Toxic Metals (mg L^{-1})	<0.1

5.9.17 In order to maintain a degree of conservatism the upper bound estimates for each of the parameters was assumed to provide input data to the water quality modelling.

(60) Scott Wilson (Hong Kong) Ltd (1999). Agreement No CE 60/96. Northshore Lantau Development Feasibility Study. Stormwater Pollution Loading Working Paper.

5.9.18 The quality of the stormwater from the commercial/developed areas was obtained from the *Stormwater Pollution Loading Working Paper*, which was prepared as part of the ongoing feasibility study for the Northshore Lantau Development[(61)]. The stormwater quality for these areas is suitable to provide input data to the water quality modelling as it represents the most up to date source of information. The stormwater quality data are presented in *Table 5.9g*.

Table 5.9g - Pollutant Concentrations in the Stormwater from the Commercial/ Developed Areas

Parameter	Concentration
Suspended Solids (mg L^{-1})	43.3
Biochemical Oxygen Demand (mg L^{-1})	22.8
Chemical Oxygen Demand (mg L^{-1})	45.8
Total Phosphorous (mg L^{-1})	0.2
Total Kjeldahl Nitrogen (mg L^{-1})	1.4
Nitrate + Nitrite (mg L^{-1})	0.4
Copper (µg L^{-1})	14.8
Lead (µg L^{-1})	9.6
Zinc (µg L^{-1})	135

5.9.19 It should be noted that in *Table 5.9f* the concentrations of nitrogen and phosphorous are higher than those in *Table 5.9g*. This due to the use of fertiliser on the landscaped areas of the theme park in Florida, which would also occur at the Theme Park in Penny's Bay.

5.9.20 In order to compare the results of the water quality modelling with the relevant Water Quality Objectives statistical analyses of water quality parameters were carried out for the identified sensitive receivers (see *Figure 5.3a*) and contours of water quality parameters for both the Baseline and Completed scenarios were produced. Both the statistical analyses of the results at sensitive receivers and contours of the water quality parameters were produced for the following.

- Dissolved oxygen - depth averaged values which are exceeded for 90% of the simulation time;
- Dissolved oxygen - bottom values which are exceeded for 90% of the simulation time;
- 5-day biochemical oxygen demand - depth averaged mean values;
- Total inorganic nitrogen - depth averaged mean values;
- Unionised ammonia - depth averaged mean values;
- Chlorophyll-a - depth averaged mean values;
- *E. coli* - depth averaged geometric mean values; and
- Suspended sediment - depth averaged maximum values.

5.9.21 In order to compare the results with the WSD criteria for abstracted sea water the water quality modelling results were analysed for the following parameters at the WSD sea water intakes.

- Dissolved oxygen - minimum surface layer concentrations;
- 5-day biochemical oxygen demand - maximum surface layer concentrations;
- Ammoniacal nitrogen - maximum surface layer concentrations;
- *E. coli* - maximum surface layer concentrations; and
- Suspended solids - maximum surface layer concentrations.

(61) Scott Wilson (Hong Kong) Ltd (1999). *Op cit*.

5.9.22 The analysis of data for comparison with the WSD criteria was undertaken for the surface layer in the water quality model because this corresponded most closely with the vertical positioning of the intakes.

5.9.23 The above analyses were carried out for the wet and dry seasons separately. The values were derived by assuming that the wet season could be represented by the period early June to mid September and the dry season by the period of late September to early April.

5.9.24 During operation of the Theme Park fireworks displays will be held nightly. The majority of the residue from the fireworks is likely to fall onto the Theme Park, where it may be transported to the stormwater system by surface run-off and then discharged to the marine waters. The fireworks residue may contain pollutants, such as metals, which, if released, to the marine waters may affect water quality.

Toxic Substances

5.9.25 There is the potential for three toxic substances to be discharged to the marine environment during the operation of the Theme Park, which are residual chlorine, pesticides and herbicides. Residual chlorine could enter the marine waters in the vicinity of the Theme Park if the water from the attractions within the Theme Park are either directly discharged or if the water is discharged to storm drains. Pesticides and herbicides could enter the marine environment through run-off from the landscaped areas entering the storm drains. If either of these substances is allowed to reach significant concentrations, then toxic effects to marine organisms could result.

Territory Wide Effects

5.9.26 The operation of the Theme Park has the potential to affect both hydrodynamics and water quality in areas remote from the development. These have been assessed by making use of both hydrodynamic and water quality models with a large area of coverage.

ARTIFICIAL LAKE

5.9.27 In order to maintain the above identified beneficial uses (see *Section 5.8.2*) for the artificial lake it is necessary that the water quality be maintained above certain standards. Although the Water Quality Objectives for inland waters of the Southern Water Control Zone (see *Table D1b* in Annex *D1*) are not directly applicable to the artificial lake, it is considered that the WQOs could be used as water quality criteria for assessing the suitability of the water quality of the artificial lake for the identified beneficial uses. However, it is recommended to adopt a stricter criterion for *E. coli* of 180 cfu $100mL^{-1}$ expressed as geometric mean, which is the objective adopted locally for bathing beaches, in order to provide a higher degree of protection to participants in water sports. The proposed water quality standards for the artificial lake are presented in *Table 5.9h*.

Table 5.9h - Proposed Water Quality Standards for the Artificial Lake

Water Quality Parameter	Standard
(a) Aesthetic appearance	• no objectionable odours or discolouration of waters; • no tarry residues, floating wood, articles made of glass, plastic or rubber; • no visible mineral oil or lasting foam on the surface; • no recognisable sewage-derived debris; • no floating, submerged and semi-submerged objects of a size likely to cause interference with the free movement of vessels or cause damage to vessels; and • no objectionable deposits.
(b) Bacteria	<180 cfu 100 mL^{-1} of *E. coli*, measured as geometric mean.
(c) Dissolved oxygen	> 4 mg L^{-1}
(d) pH	Within the range of 6 - 9
(e) Temperature	No discharges or human activities shall cause the natural daily temperature range to change by more than 2°C.
(f) Salinity	No discharges or human activities shall cause the natural daily salinity range to change by more than 10%.
(g) Suspended solids	< 25 mg L^{-1}, measured as annual median.
(h) Ammonia	< 0.021 mg L^{-1}, as unionised form, calculated as annual average.
(i) Nutrient	Not to be present in quantities sufficient to cause excessive or nuisance growth of algae or other aquatic plants.
(j) 5-day BOD	< 5 mg L^{-1}
(k) COD	<30 mg L^{-1}
(l) Dangerous substances	Not in a quantity sufficient to pose a risk to any beneficial uses of the aquatic environment.

5.9.28 An external source of water is proposed to maintain the water level in the lake during periods of low rainfall, while during the wet summer months stormwater run-off will be used as the water source. It will be necessary to determine whether the quality of these sources of water will be suitable to be used to fill the artificial lake. It is proposed that the relevant tables in the *Technical Memorandum* on *Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters* be used as a guide for determining the suitability of any discharges to the lake. It should be noted that the TM may not be directly applicable as it is generally applied to wastewater discharges to waters of Hong Kong. However, it provides useful guidance for the purposes of the assessment of water quality impacts in this Study.

5.9.29 The three beneficial uses which relate to the discharge standards are the use of the lake for irrigation, as a water recreation area and as an area of general amenity value. Under the beneficial use if irrigation the artificial lake would be classed as a Group B inland water, while under its recreation and amenity uses the lake would be classed as a Group D inland water. There are defined standards for discharges to Group B and Group D inland waters, and the standards for discharge to Group B waters are more stringent that those for Group D waters. It is therefore proposed to make reference to the standards for discharge to Group B inland waters, which are contained within *Table 4* of the *Technical Memorandum*.

5.9.30 In terms of protecting the water quality in the lake for maintaining the beneficial uses the following water quality parameters are of primary concern in the assessment.

- dissolved oxygen;
- nutrients; and
- *E. coli*.

5.9.31 If dissolved oxygen concentrations are reduced to low levels then the waters of the lake will not be able to support any aquatic life, such as ornamental fish, which would reduce the amenity value of the lake. Also, at very low dissolved oxygen concentrations anaerobic bacteria produce hydrogen sulphide, a foul smelling gas, which would again reduce the amenity value of the lake.

5.9.32 Increasing concentrations of nutrients (nitrogen and phosphorous) within the waters of the lake could lead to excessive growth of algae and aquatic plants. This would be considered an adverse impact due to the reduction in the general amenity value of the lake and the effects on water sports, such as those involving boating by fouling of vessels.

5.9.33 The health of waters sports users of the lake could be at risk if the concentrations of *E. coli* exceed the levels specified in *Section 5.8.2*. Increasing *E. coli* concentrations would also be an indicator that sewage effluent is entering the lake, which would also serve to affect both dissolved oxygen and nutrient concentrations.

5.9.34 The artificial lake is to be constructed in an area where the land may have been contaminated by the former shipyard. There may be the potential for contaminants to leach into the groundwater, which may then enter the artificial lake. The primary contaminant of concern would be TBT, which is contained within anti-foulant paints, and would have the potential to cause adverse impacts to aquatic organisms in the lake.

SEWERAGE SYSTEM

5.9.35 In order to prevent adverse impacts to water quality from the discharge of untreated sewage effluent from the Theme Park to the surrounding marine waters the sewage will be conveyed to the Siu Ho Wan STW for treatment prior to disposal to marine waters via a submarine outfall. Both the sewerage system to transport the sewage effluent and the Siu Ho Wan STW should be of sufficient capacity to cater for the effluent flows from the Theme Park. Should either system be below the required capacity then there would be the risk of/necessity for the discharge of untreated sewage to the marine waters.

5.9.36 The discharge of untreated sewage to marine waters may also occur due to the failure of the sewerage system or the emergency shut down of the system.

5.9.37 Should untreated sewage be effluent be discharged to marine water there would be the potential of adverse impacts to water quality. The extent of such impacts would be related to the quantities and duration of any discharges. The impacts would likely be in the form of elevated *E. coli* concentrations, which would primarily cause adverse effects on bathing beaches and secondary contact recreation sub-zones, decreased dissolved oxygen concentrations, affecting marine ecology and fish culture zones and increased nutrient levels, which would increase the risk of algal growth.

ROAD AND RAIL LINKS

5.9.38 Run-off from the road links will enter the stormwater drainage system in Penny's Bay and Yam O before being discharged to the surrounding marine waters. The run-off may contain a number of pollutants that result from the normal wear and tear of road vehicles, including suspended solids, adsorbed pollutants such as heavy metals and PAHs and petroleum products such as oil and grease.

5.9.39 The potential sources of impacts to water quality from the operation of the PBRL have been identified as follows.

- Surface track runoff during rainfall may be contaminated with oil, grease and SS arising from track grindings, corrosion of rolling stock, and passing trains, which may cause downstream impacts on the stormwater system;
- Drainage from the tunnel will comprise groundwater seepage to the outer tunnel lining, which will be uncontaminated and may therefore be discharged directed to the stormwater drainage system.
- Rainwater runoff from the station structure, such as the station roofs, is expected to be "clean" and may therefore be discharged directly to the stormwater system.
- Sewage effluent will be generated at the stations, where staff toilet facilities will be provided. Uncontrolled discharge of sewage will cause unacceptable water quality impacts to the receiving waters.
- A train washing plant will be situated between the refuge siding and the Theme Park Station, which will employ mechanic scrubbers and detergent to clean the trains. Uncontrolled discharge of detergent contaminated water would have the potential to cause adverse impacts.

5.10 ASSESSMENT OF ENVIRONMENTAL IMPACTS - OPERATION

5.10.1 The assessment of impacts to water quality from the operation of the Theme Park is split into three main aspects.

- The surrounding marine waters;
- The artificial lake; and
- The adequacy of the sewerage system, including the Siu Ho Wan Sewage Treatment Works (STW).

MARINE WATERS

5.10.2 The operation of the Theme Park will have the potential to affect the water quality of the surrounding marine waters in two ways, by changing the hydrodynamics and through the discharges of pollutants from the Theme Park. These two aspects have been assessed separately using computational modelling.

Hydrodynamics

5.10.3 The residual discharges across major flow channels are shown in *Table 5.10a* for both the Baseline and Completed Scenarios and include a calculation of the percentage differences between the Completed and Baseline Scenarios. The average flood and ebb discharges are shown in *Tables 5.10b* and *5.10c*, including a calculation of the percentage differences between the Completed and Baseline scenarios.

Table 5.10a - Residual Discharges (m^3s^{-1}) through Major Flow Channels

Channel	Wet Season			Dry Season		
	Baseline Discharge	Completed		Baseline Discharge	Completed	
		Discharge	Difference (%)		Discharge	Difference (%)
Urmston Road	799	789	-1.3	1480	1475	-0.3
Kap Shui Mun	-164	-148	-9.8	651	634	-2.6
Ma Wan Channel	1527	1486	-2.7	1111	1121	0.9
Rambler Channel	-564	-549	-2.7	-284	-283	-0.4
East Lamma Channel	1823	1807	-0.9	1226	1216	-0.8
West Lamma Channel	-1563	-1531	-2.0	-512	-483	-5.7
Victoria Harbour	-120	-123	2.5	1058	1056	-0.2

1. Positive discharge is in the flood direction, as defined on *Figure 5.9a*.
2. Positive change represents an increase in discharge and a negative change a decrease in discharge.

Table 5.10b - Average Flood Discharges (m^3s^{-1}) through Major Flow Channels

Channel	Wet Season			Dry Season		
	Baseline Discharge	Completed		Baseline Discharge	Completed	
		Discharge	Difference (%)		Discharge	Difference (%)
Urmston Road	24446	24375	-0.3	26346	26288	-0.2
Kap Shui Mun	5718	5692	-0.5	7001	6955	-0.7
Ma Wan Channel	15332	15251	-0.5	16205	16159	-0.3
Rambler Channel	776	789	1.7	1065	1071	0.6
East Lamma Channel	13845	13809	-0.3	14370	14350	-0.1
West Lamma Channel	10549	10439	-1.0	11343	11239	-0.9
Victoria Harbour	3765	3765	0.0	4504	4499	-0.1

Table 5.10c - Average Ebb Discharges (m^3s^{-1}) through Major Flow Channels

Channel	Wet Season			Dry Season		
	Baseline Discharge	Completed		Baseline Discharge	Completed	
		Discharge	Difference (%)		Discharge	Difference (%)
Urmston Road	22718	22669	-0.2	23212	23160	-0.2
Kap Shui Mun	6043	5984	-1.0	5761	5747	-0.2
Ma Wan Channel	12596	12589	-0.1	14142	14075	-0.5
Rambler Channel	2128	2075	-2.5	1688	1689	0.1
East Lamma Channel	10567	10554	-0.1	12090	12084	0.0
West Lamma Channel	13670	13493	-1.3	12358	12195	-1.3
Victoria Harbour	4000	4004	0.1	2666	2667	0.0

5.10.4 The data in the above tables show that in the wet season the Penny's Bay reclamation for the Theme Park causes small changes of less than 3% in the average flood and ebb discharges through the flow channels. The same assessment may be made for the residual discharges, except for Kap Shui Mun. The Baseline residual discharges through Kap Shui Mun, however, are small and a small absolute change in discharge results in a relatively large percentage difference. The predicted changes in discharge through Kap Shui Mun are, therefore, not considered to be significant.

5.10.5 In the dry season the data in the tables show that the Penny's Bay reclamation for the Theme Park causes small changes, less than 1.5%, in the average flood and ebb discharges through the flow channels. The changes in residual discharges are larger, although they are still less than 3% which is considered small, except for the West Lamma Channel where there is a 5.7% decrease. The absolute change in residual discharge through the West Lamma Channel is small, but when compared with the Baseline discharges, which is relatively low compared to the other main flow channels, this results in a larger relative change. The decrease in residual flows through the West Lamma Channel is therefore not considered to be significant.

5.10.6 The graphs of momentary of cumulative discharges for the wet season are shown in *Figures D2a* to *D2g* in *Annex D2*. For all of the cross section there is little discernible difference between the Baseline and Completed scenarios, which demonstrates the lack of effect of the Theme Park reclamation on tidal discharges in the wet season. The graphs of momentary of cumulative discharges for the dry season are shown in *Figures D2h* to *D2n* in *Annex D2*. There are no discernible differences between the Baseline and Completed scenarios, as for the wet season, and indicates the minimal effects of the reclamation on tidal discharges in the dry season.

5.10.7 Vector plots of current speed and direction for the wet season, which also include contours of salinity, are presented in *Figures D2o* to *D2r* in *Annex D2*. The Theme Park reclamations are predicted to have a small impacts on tidal current patterns, as can be seen by comparing *Figures D2q* and *D2r* with *Figures D2o* and *D2p*. The only discernible differences are at the eastern and western ends of the Penny's Bay reclamation. At the eastern end there is predicted to be a slight increase in current speed as the currents turn into Kap Shui Mun from the face of the reclamation, while at the western end current speeds reduce slightly in Sze Pak Wan due to the sheltering effect of the reclamation. The only differences in salinity are found in the bed layer, where there are predicted to be small increases in salinity to the west of the Penny's Bay reclamation in the vicinity of Discovery Bay, which indicates a decrease in flushing in this area. The effects of the predicted reduction in flushing has been determined through water quality modelling and is discussed below.

5.10.8 Vector plots of current speed and direction for the dry season are shown on *Figures D2s* to *D2v* in *Annex D2*. The patterns of current speed change are similar to those for the wet season, which have been discussed in detail above. No further discussion is therefore necessary here.

Water Quality

5.10.9 The results of the water quality modelling at sensitive receivers are contained in *Tables 5.10d* and *5.10e* for the wet and dry seasons respectively. In these tables the water quality modelling results are presented as statistical parameters (10^{th} percentile, mean, geometric mean and maximum) for comparison against the Water Quality Objectives. The locations of the sensitive receivers are shown in *Figure 5.3a*. In *Tables 5.10f* and *5.10g* the water quality modelling results have been analysed to provide relevant statistical comparisons (minimum and maximum) for comparison against the Water Supplies Department's criteria for seawater intakes in the wet and dry seasons respectively.

5.10.10 The data in *Tables 5.10d* and *5.10e* show that the water quality modelling predicts there will be no exceedances of the WQO for dissolved oxygen, unionised ammonia and suspended solids. There are predicted to be minimal changes in dissolved oxygen concentrations, except at Discovery Bay Beach and Sze Pak Wan in the wet season. At Discover Bay Beach the dissolved oxygen concentrations in the bottom of the water column are predicted to decrease from 3.7 mg L^{-1} to 3.4 mg L^{-1}, which is most likely to a decrease in the flushing of this area resulting from the sheltering effect of the Penny's Bay reclamation for the Theme Park. However, this impact is not considered to be adverse as the WQO is not predicted to be breached. At Sze Pak Wan both the depth averaged and bottom dissolved oxygen concentrations are predicted to increase and this is most likely due to the reduced flushing of this area providing conditions more conducive to algal growth, as shown by the increase in chlorophyll-*a* concentrations.

5.10.11 There are predicted to be a number of exceedances of the WQO for total inorganic nitrogen in both the wet and dry seasons. However, in all cases the exceedances are predicted to occur in both the Baseline and Completed scenario and it may be concluded that the operation of the Theme Park is not contributing to the exceedance of the WQO. Furthermore, the operation of the Theme Park is not predicted to increase the level of exceedance of the WQO. There are predicted to be only small changes in the chlorophyll-*a* concentrations as a result of the operation of the Theme Park. At Sze Pak Wan concentrations increase from 5.4 $\mu g\ L^{-1}$ to 8.2 $\mu g\ L^{-1}$ in the dry season and from 9.1 $\mu g\ L^{-1}$ to 11.0 $\mu g\ L^{-1}$ in the wet season. It is assessed that these changes do not represent excessive or nuisance growths of algae and as such should not be considered as an adverse impact.

5.10.12 Exceedances of the WQO for *E. coli* at bathing beaches are predicted to occur in both the wet and dry seasons. In all cases the operation of the Theme Park is not predicted to contribute to the level of exceedances, and only results in small increases at a few of the bathing beaches. It is therefore assessed that the Theme Park is not causing adverse impacts in terms of *E. coli* concentrations.

5.10.13 The data in *Tables 5.10f* and *5.10g* show that the water quality modelling results predict that there will be exceedances of WSDs criteria at a number of seawater intakes, primarily in terms of *E. coli* concentrations. However, these exceedances are predicted to occur in both the Baseline and Completed scenarios and it can be seen that the operation of the Theme Park is not contributing significantly to the levels of exceedance of these standards. It is therefore assessed that the operation of the Theme Park is not causing adverse impact to the water quality at WSDs intakes.

5.10.14 Contours of water quality parameters are contained in *Annex D3*, in *Figures D3a* to *D3p* for both the Baseline and Completed scenarios. The contours represent the same values as those shown in the tables above and are therefore suitable for direct comparison with the Water Quality Objectives. The contours of dissolved oxygen (*Figures D3a* to *D3d*) show little differences in dissolved oxygen concentrations in the wet and dry season between the Baseline and Completed scenarios. The most apparent changes are shown in the wet season for depth average and bottom concentrations (*Figures D3a* and *D3c* respectively). For the depth average concentrations there is shown to be an increase in concentrations in Sze Pak Wan, which has been explained above by the increase in algal growth in this area, and a small decrease in concentrations around Hei Ling Chau. In the bottom layer there is predicted to be a decrease in concentrations around Peng Chau and again an increase in Sze Pak Wan. None of these changes are predicted to cause a breach of the WQO and as such are considered to be acceptable. There is predicted to be a small decrease in BOD concentrations in the vicinity of Peng Chau as a result of the operation of the Theme Park in the dry season (*Figure D3f*), which would be considered to be an environmental improvement. No other changes in BOD concentrations are evident from the contour plots.

5.10.15 The contours of total inorganic nitrogen (*Figures D3g* and *D3f*) demonstrate that the major source of this pollutant in the waters around the Theme Park is the outflow from the Pearl River Estuary. The contour plots show only minimal differences between the Baseline and Completed scenarios for the wet and dry seasons, the most obvious of which is evident around the outfall from the Siu Ho Wan STW. This change is shown to be a slight increase in concentrations, which does not result in an exceedance of the WQO in the vicinity of the outfall. This impact is therefore considered to be environmentally acceptable. The only changes in the unionised ammonia concentrations (*Figures D3i* and *D3j*) are predicted to occur in the vicinity of Silvermine Bay, where concentrations are predicted to marginally increase but do not breach the WQO for this parameters. This impact is therefore considered to be environmentally acceptable.

5.10.16 Contours of chlorophyll-a concentrations are contained in *Figures D3k* and *D3l* and show that the water quality predicts only small changes in this parameters as a result of the operation of the Theme Park. The modelling predicts increases in chlorophyll-a concentrations in Sze Pak Wan and Yam O Wan. However, these increases are not considered to be excessive and would therefore not constitute a breach of the WQOs.

5.10.17 The contours of geometric mean *E. coli* concentrations (*Figures D3m* and *D3n*) show that the modelling only predicts changes in this parameter in the vicinity of the Peng Chau sewage outfall. The concentration in the areas offshore of Sze Pak Wan and Discovery Bay are predicted to increase marginally. However, in these two areas the concentrations are predicted to remain below 610 cfu 100mL^{-1}, the WQO for secondary contact recreation sub-zones, and as such are considered to be environmentally acceptable. Offshore of the developments along the north Lantau coast the concentrations are also predicted to remain below that for secondary contact recreation sub-zones.

5.10.18 The contours of maximum suspended sediment concentrations (*Figures D3o* and *D3p*) show that the modelling predicts no discernible differences in suspended sediment concentrations between the Baseline and Completed scenarios.

5.10.19 The water quality modelling has predicted that there will be no exceedances of the WQO at sensitive receivers due to the sewage effluent and stormwater discharges from the operation of the Theme Park. There are, however, a number of exceedances of the WQO predicted for the Baseline and Operation scenarios, but in these cases the operation of the Theme Park is not contributing to the exceedance. The only exceedance of a WQO due to the operation of the Theme Park is predicted to be in the vicinity of the discharge point for the Siu Ho Wan STW outfall, where the area of exceedance from the Baseline to Operation scenarios is predicted to increase marginally. However, the increased area of exceedance is in open water and does not contain any sensitive receivers. The operation of the Theme Park in terms of sewage effluent and stormwater discharges is therefore not expected to cause adverse impacts to water quality.

5.10.20 The potential impacts to water quality may be readily controlled through suitable mitigation measures, which are described in *Section 5.10.1*.

Toxic Substances

5.10.21 The potential adverse impacts to water quality from the discharge of toxic substances during normal operating conditions may be readily controlled by appropriate measures at the Theme Park to minimise the effects, which are described in *Section 5.11.1*.

5.10.22 In the event of an emergency requiring complete shut down of the water attractions, such as mechanical failure, it may be necessary to empty the rides. In this case it is likely that the water will be discharged to the nearby marine waters. There would therefore be the potential for adverse impacts to the marine ecosystem. However, the frequency of such events is likely to be small and the adverse impacts would be of short duration, ie during discharge and the time taken for the residual chlorine to dissipate. In view of the infrequent and short duration nature of these impacts it is considered that there will not be the need for mitigation measures.

Territory Wide Effects

5.10.23 The hydrodynamic modelling predicted that the Theme Park reclamations would only affect tidal current speeds and directions local to the Theme Park, most noticeably in a reduction in current speeds to the south west of the Theme Park, and thus broader territory-wide impacts are not predicted to occur.

5.10.24 The operational water quality modelling predicted that there would be no breaches of the Water Quality Objectives due to the sewage effluent and stormwater discharges from the operation of the Theme Park and associated developments. It was also predicted that the water quality in the areas to the south west of the Theme Park would be acceptable. It is therefore concluded that there would be no adverse impacts to water quality due to sewage effluent and stormwater discharges from the Theme Park and thus broader territorial impacts to water quality are not, therefore, predicted to arise from the operation of the Theme Park and associated developments.

ARTIFICIAL LAKE

5.10.25 The level of the water in the artificial lake will be limited to a level of 1 m below +7.5 mPD. Water will be extracted from the lake to provide irrigation waters for the landscaped areas of the Theme Park. In the wet summer months the waters within the lake will be replenished with run-off from the surrounding undeveloped hillsides. In the months when rainfall is low the waters of the lake will be replenished with waters from an external source. The water quality in the lake will therefore be a function of the quality of the water used to replenish the waters levels.

5.10.26 The stormwater run-off, used to replenish the lake during the wet summer months, will be essentially free of pollutants as it will not pass through any urban, developed areas. These waters may, however, contain high levels of suspended sediments and in order to prevent siltation within the reservoir will pass through silt traps before being discharged to the lake. Therefore, during the wet summer months water quality within the lake will be maintained.

5.10.27 Another factor associated with the operation of the lake during periods of high rainfall is that there will be an overflow weir to prevent the water level from exceeding +7.5 mPD. The overflow water will pass along the open drainage channel on the western side of the Theme Park reclamation at Penny’s Bay and discharged to marine waters. It is to be expected that this water will be relatively free of contaminants, having come from a clean water source (ie the lake) and as such adverse impacts to marine water quality are not expected. The only potential impact will be to salinity in the immediate vicinity of the discharge point, which is likely to be lowered by the incoming fresh water. The natural, background salinity will soon be restored following the cessation of overflow from the lake. Therefore this potential impact will be short term and reversible in nature and will not therefore give rise to adverse impacts to the marine environment.

5.10.28 The major concern for the water quality of the lake will be from the replenishment of the water levels from an outside source during periods of low rainfall. It will be necessary to ensure that the quality of the water used to replenish will not cause the water quality within the lake to deteriorate. The Tai Lam Chung Reservoir has been identified by the Water Supplies Department (62) as a potential source of water to replenish the lake. A summary of the measured quality of the lake for the period 1998 to 1999 compared with the standards in the *Technical Memorandum* for *Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters* (TM) for waters discharged into Group B inland waters is given in *Table 5.10h*. A comparison of the quality of the water in the Tai Lam Chung Reservoir with the proposed water quality criteria, which were derived based on the WQOs for inland waters in the Southern WCZ. These comparisons provides useful guidance on the quality of the water used to fill the lake during dry periods.

Table 5.10h - Measured Water Quality in the Tai Lam Chung Reservoir in 1998 - 1999 Compared with the TM Standards

Parameter	Maximum	Minimum	Mean	TM Standard

(62) Communication with WSD.

Parameter	Maximum	Minimum	Mean	TM Standard
pH	7.5	6.6	7.2	6.5 - 8.5
Temperature (°C)	31.0	15.8	22.5	30 - 35
Colour (HU)	8	<5	<5	Not comparable
Suspended Solids (mg L^{-1})	6	1	4	30
DO (mg L^{-1})	8.8	1.1	7.0	No standard
BOD (mg L^{-1})	5.1	0.3	2.4	20
Iron (mg L^{-1})	0.15	<0.01	0.06	1 - 10
Cyanide (mg L^{-1})	<0.05	<0.05	<0.05	0.03 - 0.1
Fluorides (mg L^{-1})	0.53	0.18	0.36	3 - 10
Sulphates (mg L^{-1})	12	6	9	400 - 800
Chlorides (mg L^{-1})	14	5	10	400 - 1000
Phosphate (mg L^{-1})	0.27	0.03	0.09	No standard
Ammonia (mg L^{-1})	0.51	0.02	0.09	5
Nitrate (mg L^{-1})	3.00	0.38	1.75	No standard
Nitrite (mg L^{-1})	0.120	0.003	0.031	No Standard
Nitrate + Nitrite (mg L^{-1})	3.120	0.383	1.781	10 - 30
Chlorophyll-a (µg L^{-1})	43	3	21	No standard
E. coli (cfu $100mL^{-1}$)	55	3	22	100
Boron (mg L^{-1})	<0.07	<0.07	<0.07	0.5 - 5
Barium (mg L^{-1})	0.015	0.013	0.014	0.5 - 5
Mercury (mg L^{-1})	<0.00005	<0.00005	<0.00005	0.001
Cadmium (mg L^{-1})	<0.0001	<0.0001	<0.0001	0.001
Selenium (mg L^{-1})	<0.001	<0.001	<0.001	0.1 - 0.2

Table 5.10I - Comparison of the Water Quality of Tai Lam Chung Reservoir in 1998 - 1999 with the Proposed Water Quality Standards

Parameter	Standard	Water Quality in Tai lam Chung Reservoir
(a) Aesthetic appearance	• no objectionable odours or discolouration of waters; • no tarry residues, floating wood, articles made of glass, plastic or rubber; • no visible mineral oil or lasting foam on the surface; • no recognisable sewage-derived debris; • no floating, submerged and semi-submerged objects of a size likely to cause interference with the free movement of vessels or cause damage to vessels; and • no objectionable deposits.	-
(b) Bacteria	<180 cfu 100 mL^{-1} of *E. coli*, measured as geometric mean.	22 cfu 100 mL^{-1} (mean)
(c) Dissolved oxygen	> 4 mg L^{-1}	1.1 mg L^{-1} (minimum) 7.0 mg L^{-1} (mean)
(d) pH	Within the range of 6 - 9	6.6 - 7.5
(e) Temperature	No discharges or human activities shall cause the natural daily temperature range to change by more than 2°C.	15.8°C - 31.0°C
(f) Salinity	No discharges or human activities shall cause the natural daily salinity range to change by more than 10%.	Not measured.
(g) Suspended solids	< 25 mg L^{-1}, measured as annual median.	4 mg L^{-1} (mean)
(h) Ammonia	< 0.021 mg L^{-1}, as unionised form, calculated as annual average.	0.09 mg L^{-1} ammonia (mean), equivalent to less than 0.01 mg L^{-1} unionised ammonia at pH 7.2 and temperature 22.2°C
(i) Nutrient	Not to be present in quantities sufficient to cause excessive or nuisance growth of algae or other aquatic plants.	Phosphate 0.09 mg L^{-1} (mean) Total inorganic nitrogen 1.861 (mean)
(j) 5-day BOD	< 5 mg L^{-1}	5.1 mg L^{-1} (maximum) 2.4 mg L^{-1} (mean)
(k) COD	<30 mg L^{-1}	Not measured.
(l) Dangerous substances	Not in a quantity sufficient to pose a risk to any beneficial uses of the aquatic environment.	-

5.10.29 The data in the *Table 5.10h* show that the quality of the water is generally not outside of the TM standards, except for temperature. This is not considered to be a problem because the water will be transferred from one open body of water (the Tai Lam Chung Reservoir) to another open body of water (the artificial lake) and the ambient temperatures of each will be similar and as such the temperature of the artificial lake will not be modified by the incoming water.

5.10.30 The data in *Table 5.10i* show that water used to fill the lake is generally at least as good as the proposed water quality criteria. Thus the water quality of the water in the lake, which originates from a combination of clean run-off from the surrounding hillsides and water from the Tai Lam Chung Reservoir, will generally satisfy the water quality criteria as its quality will be at least as good as the water used to fill the lake. The exceptions to this are dissolved oxygen and BOD. On only one occasion during the monitoring period the value of dissolved oxygen was less than 6 mg L^{-1} (ie 1.1 mg L^{-1}), which is water quality criterion of 4 mg L^{-1}. However, this is considered to be an exceptional event, possibly linked to mortality of algae following a period of excessive algal growth. The maximum value for BOD is just greater than the proposed water quality criterion of 5 mg L^{-1}, therefore it is considered unlikely that this standard will be breached as the incoming water will be diluted with the water in the lake.

5.10.31 The above assessment has concluded that the quality of the water within the lake may be maintained by using the water from the Tai Lam Chung Reservoir as the source of water during periods of low rainfall. It has been assumed that there will be no other sources of pollutants into the lake and therefore controls on any potential sources of pollutants should be implemented , which are discussed in *Section 5.11.2*.

5.10.32 There may be the potential for the accidental discharge of petroleum products, which are used to fuel boats used for water sports. Suitable mitigation measures have been devised to minimise the likelihood of such events and if the unlikely event of such an occurrence measures to control the impact have been devised (see *Section 5.11.2*).

5.10.33 The lining for the artificial lake will be constructed from a high density polyethylene (HDPE) geomembrane, which is impermeable, sandwiched between protective geotextiles. The use of such a liner will prevent the migration of contaminated groundwater into the lake, which means that the quality of the water in the lake will not be affected by any pollutants contained within the groundwater.

SEWERAGE SYSTEM

5.10.34 The sewerage system to be used for the Theme Park was originally designed to accommodate the flows from the previous planning proposals for the Penny's Bay area, which principally comprised Container Terminals 10 and 11 and the associated back-up areas. The sewerage system comprises two principal sewers in the Penny's Bay area, which may be described as follows.

- The ring road to the south of the park defines the route of a sewer that will collect all sewage from the area to the south of the railway line that bisects the site. The sewer will convey flows from east to west, ultimately to a pumping station north east of the Theme Park. Due to the distance involved and the requirement to minimise excavation in a reclaimed area, a gravity system with lift pumping stations at approximately 300m intervals will be required along the ring road. The pumping stations will comprise underground chambers housing submersible pumps. There will be a small control kiosk above-ground (say 2mx2mx1m) housing telemetry and control equipment. The pumps will operate to ensure that under normal flow conditions the sewer will not surcharge and flushing velocities will be maintained. In the event of pump failure the system will surcharge and operate by gravity and flooding will not occur under this condition.

- A sewer following the road on the north boundary of the Penny's Bay Theme Park site will collect flow from the north of the railway line that bisects the site. This sewer will convey flow from east to west to the pumping station to the north east of the Theme Park.

5.10.35 The pumping station in the utility yard to the north-east of the Penny's Bay theme park will convey flows via twin rising mains northwards to the previously constructed gravity main that conveys flows to the Yam O Sewage Pumping Station. There will be an emergency overflow into the adjacent drainage channel to the west. A standby pump will be provided together with twin rising mains which provide for a situation whereby one of the rising mains is temporarily taken out of operation. The anticipated frequency of discharge through the emergency outfall will be very low.

5.10.36 The Yam O Pumping Station is to be completed in advance of the development. The pumping station will convey flows to SHWSTW via twin 700 mm diameter pumping mains approximately 4,000 m in length. One of the 700 mm diameter mains is already in place and the second main would be constructed in the same service reserve when required as the phased development proceeds.

5.10.37 In order to assess the adequacy of the sewerage system to convey the sewage effluents from the Theme Park to the Siu Ho Wan STW it is first necessary to determine the quantities of sewage effluent generated by the Theme Park. The operator of the Theme Park has provided information on daily average flow rates and peak flow rates, based on their experience with similar facilities in other parts of the world. The predicted flows have been provided based on various phases of the development of the Theme Park. The average daily flows and instantaneous peak flows are presented in *Table 5.10i*.

Table 5.10i - Average Daily and Peak Sewage Effluent Flows from the Theme Park

Development Scenario	Average Daily Flow (m^3 day^{-1})	Peak Flow (m^3 s^{-1})
Opening Day (2005)	2,706	0.182
Phase 1 Buildout (2011)	5,593	0.360
Phase 2 Buildout (2024)	12,140	0.776

5.10.38 The sewerage system within the Theme Park has yet to undergo detailed design to cater for the above average and peak daily flows. The design should ensure that the system is adequate with a suitable factor of safety to minimise the risk of failure, following procedures defined in the DSD *Sewerage Manual*.

5.10.39 A design for upgrading the Siu Ho Wan STW is currently being carried out to increase the capacity of the STW and to provide a higher level of treatment for the sewage effluent prior to discharge. The design flows have been calculated based on the development of container terminals in Penny’s Bay and the connection of sewage flows from Peng Chau. It is now not proposed to connect the sewage from Peng Chau to the Siu Ho Wan STW and it will continue to discharge of Tai Lei. Due to the changes in the sewage effluents to be transported to the Siu Ho Wan STW it is necessary to determine whether the STW will be able to accommodate the changes in sewage effluent flows due to the development of the Theme Park. The future cumulative flows to the Siu Ho Wan STW are presented in *Table 5.10j*, which includes flows for 2005 (the Theme Park opening day), 2011 and the ultimate development beyond 2011.

Table 5.10j - Cumulative Sewage Effluent Flows to the Siu Ho Wan STW

Source	2005		2011		Ultimate	
	Average Flow (m^3 day^{-1})	Peak Flow[d] (m^3 s^{-1})	Average Flow (m^3 day^{-1})	Peak Flow[e] (m^3 s^{-1})	Average Flow (m^3 day^{-1})	Peak Flow[e] (m^3 s^{-1})
Chek Lap Kok Airport[a]	16.586	0.334	16,586	0.466	27,434	0.762
Tung Chung/Tai Ho[a]	130,860	2.605	130,860	3.635	130,860	3.635
Discovery Bay[b]	9,250	0.184	9,250	0.257	9,250	0.257
South Lantau[a]	-	-	-	-	12,610	0.350
Theme Park[c]	2,706	0.054	5,593	0.155	12,140	0.338
Total	159,402	3.177	162,289	4.513	192,294	5.342

Notes :

a. Data derived from the *Final Design Memorandum* for the Siu Ho Wan STW.
b. Data calculated assuming a residential population and flow factors given in the DSD *Sewerage Manual*.
c. Data on average flows provided by the Theme Park operator.
d. Peak flows calculated based upon a peaking factor of 1.72, which represents a new system without infiltration.
e. Peak flows calculated based upon a peaking factor of 2.40, which includes an allowance for infiltration.

5.10.40 It should be noted that in the above table the peak flows from the Theme Park are different from those contained in *Table 5.10i*. This is because the data in *Table 5.10i* represents the peak flows within the sewerage system in and adjacent to the Theme Park, while the data in the above table represents the peak flows at the Siu Ho Wan STW. The differences are because there will be attenuation of the peaks in the flows between the Theme Park and the Siu Ho Wan STW.

5.10.41 The peaking factor of 1.72 used in the *Final Design Memorandum* for the Siu Ho Wan STW is based upon the assumption that the sewerage system is relatively new and free from inflow/infiltration, which is applicable to the 2005 scenario. For the 2011 and Ultimate scenarios the peaking factor has been increased to one which includes an allowance for inflow/infiltration to account for potential deterioration of the network.

5.10.42 The design flows for the Siu Ho Wan STW are shown in *Table 5.10k* and are derived from the *Final Design Memorandum* and upon advice provided by the Drainage Services Department.

Table 5.10k - Design Sewage Flows for the Siu Ho Wan STW

Year/Design Horizon	Average Flow (m^3 day^{-1})	Peak Flow (m^3 s^{-1})
Up to 2011	179,433	3.75
Ultimate	202,881	4.226

5.10.43 A comparison of the data in *Tables 5.10j* and *5.10k* show that the predicted average flows are predicted to be within the design capacity of the Siu Ho Wan STW. The data show that in 2005 at the opening of the Theme Park the peak flows are predicted to be within the design capacity of the Siu Ho Wan STW. However, in 2011 and for the Ultimate case the peak flows are predicted to exceed the design capacity of the Siu Ho Wan STW, assuming a peaking factor which allows for infiltration/inflow. It will therefore be necessary to carry out upgrading works at the Siu Ho Wan STW prior to 2011 to prevent overloading of the STW and the potential for overflow of untreated sewage effluent.

5.10.44 It should be noted that the assessment is carried out to determine whether increased flows from the Theme Park would result in overloading the Siu Ho Wan STW. Other developments associated with the Northshore Lantau Development will also contribute sewage effluent flows to the Siu Ho Wan STW. The effects of these other flows are being investigated as part of the *Northshore Lantau Development Feasibility Study*.

5.10.45 The major cause of emergency discharge from either the sewerage system or the Siu Ho Wan STW will be from overflows from the system or bypassing at the STW. However, as discussed above, with the implementation of an upgrade to the Siu Ho Wan STW the sewerage system will be designed to cater for the predicted sewage effluent flows generated by the Theme Park and that with the increased flows from the Theme Park the Siu Ho Wan STW will not exceed the design capacity of the STW. Therefore the risk of overflows from and bypassing of the STW will be low, although certain measures may be installed to ensure that the risk is reduced further. It should be noted that any measures for reducing the risk of over-flow at the Siu Ho Wan STW will be the responsibility of the Drainage Services Department and not the Theme Park developer or operator.

5.10.46 There may be a risk of failure of systems, such as pumping stations, which could result in the discharge of raw sewage to the surrounding waters for periods of days. Such discharges would be likely to lead to adverse water quality impacts and should therefore be prevented through the provision of suitable redundant/back-up systems.

5.10.47 Sewers constructed using the standard flexible joint systems found on concrete or clayware pipes often perform badly in reclaimed land due to differential settlement. This can result in high levels of infiltration or exfiltration, depending upon the level of the pipes in relation to the water table. Infiltration will cause capacity problems in the sewer network and at the STW, while exfiltration will pollute groundwater and ultimately the surrounding marine waters. It will be necessary to utilise alternate types of pipe and jointing to prevent such problems.

ROAD AND RAIL LINKS

5.10.48 The identified potential impacts to water quality from the operation of the road and rail links may be readily controlled through engineering design and the implementation of suitable operating procedures. There is therefore no further assessment of impacts carried out here.

5.11 MITIGATION OF ADVERSE ENVIRONMENTAL IMPACTS - OPERATION

5.11.1 The identification and discussion of suitable measures to mitigate any adverse impacts to water quality from the operation of the Theme Park is split into four main aspects.

- The surrounding marine waters;
- The artificial lake;
- The adequacy of the sewerage system, including the Siu Ho Wan Sewage Treatment Works (STW); and
- Road and rail links.

MARINE WATERS

5.11.2 The operation of the Theme Park will have the potential to affect the water quality of the surrounding marine waters in two ways, by changing the hydrodynamics and through the discharges of pollutants from the Theme Park. Any mitigation measures for these two aspects are discussed separately.

Hydrodynamics

5.11.3 The hydrodynamic modelling has predicted that the reclamations for the Theme Park at penny's Bay and Yam O will have minimal effects on tidal discharges through major flows channels. The only effects on tidal current speeds and directions are in the immediate vicinity of the reclamation at Penny's Bay, which are not considered to be significant. Mitigation measures for changes to tidal discharges and current patterns are therefore not considered to be necessary.

5.11.4 The modelling has, however, predicted that there will be a reduction in the flushing of Sze Pak Wan and Discovery Bay, as demonstrated by the increased salinity in these areas. This effect may cause changes in the water quality of these areas. The acceptability of such changes has been assessed through water quality modelling, which has determined whether such impacts would be acceptable. The need for mitigation measures in these two areas is discussed below.

Water Quality

5.11.5 The water quality modelling has predicted that the sewage effluent and stormwater discharges from the operation of the Theme Park will not cause adverse impacts to water quality. However, on a precautionary principle it is recommended that all storm water will pass through silt trap within the Theme Park and Commercial/Developed areas prior to entering the stormwater system. This will serve to ensure that the pollutants in the stormwater discharges are minimised as far as is practicable. The assessment also assumes that the Siu Ho Wan Sewage Treatment Works will be able to cater for the increased flows from the Theme Park, whilst maintaining the same level of treatment. Mitigation measures for this aspect are discussed below.

5.11.6 In order to control the potential impacts to water quality from fireworks residue it is recommended that large pieces of spent fireworks be collected as soon after the completion of the display as is practicable. The measure of installing silt traps, described above, will then serve to prevent smaller particles from being discharged to the marine waters.

Toxic Substances

5.11.7 During operation of the attractions the water will be dosed with sodium hypochlorite, which acts as a disinfecting agent and as a biocide. Under normal operating conditions the water will be re-cycled around the rides and should not be allowed to be discharged to either storm drains or the nearby marine waters. However, during routine maintenance the water from the attractions will be emptied. In this case monitoring of the residual chlorine concentration should be undertaken and discharge of the water only allowed once the concentration is below 0.01 mg L^{-1}, which is the level at which EPD have expressed concern [63]. This measure will prevent the discharge of harmful quantities of residual chlorine during routine maintenance and hence prevent adverse impacts to water quality.

5.11.8 The discharge of pesticides and herbicides in harmful quantities should be prevented through the implementation of the following measures.

- the construction of trenches, backfilled with loose soil or similar porous material, around any areas where pesticides and herbicides will be used;
- pesticides and herbicides should not be used during periods of rainfall; and
- biodegradable pesticides and herbicides with short half-lives of three days or less.

5.11.9 The measure of constructing trenches around any areas where pesticides and herbicides will ensure that the first flush of run-off from these areas, which is likely to contain the highest concentrations of pesticides and herbicides, will be absorbed in the material filling the trench and prevented from entering the stormwater system. The prevention of the application of pesticides and herbicides during periods of rainfall will prevent run-off of the substances immediately after application and allow some time for the substances to degrade, particularly through the use of substances which are biodegradable with short half lives. In order to determine compliance with these measures a log book detailing the application of any pesticides or herbicides should be kept, containing such information as date and time, location of application, quantities applied, pesticide/herbicide used and weather conditions.

ARTIFICIAL LAKE

5.11.10 During the wet summer months stormwater run-off from the surrounding hillsides will be used to provide water to fill the artificial lake. Prior to entering the lake the stormwater will pass through silt traps to prevent siltation within the lake. The silt traps should be designed to have adequate capacity to retain any silt/sediment contained within the stormwater. The silt traps should be frequently maintained/cleaned to prevent a deterioration in performance.

5.11.11 During months with low rainfall it is proposed that water from the Tai lam Chung Reservoir be used to 'top up' the water within the lake. At present the quality of the water within the reservoir is sufficient to maintain the quality of the water within the lake. However, if in future the quality of the water in the lake were to deteriorate below the present levels, particularly with regard to *E. coli* concentrations, then it would be necessary to adopt an alternate supply of water. The alternate supply of water should be at least as good as the current standard of the water within the Tai lam Chung Reservoir.

5.11.12 A potential concern with regard to the quality of the lake could be algal growth. If growth becomes excessive then it may be necessary to add an algicide to the waters of the lake. The algicide should be biodegradable with a short half life of three days or less. During use of the algicide, discharge of the lake water to marine waters should be prohibited, until the algicide has decayed. This means that the algicide may not be used during periods of heavy rainfall, when overflow of the lake is possible.

5.11.13 Stormwater run-off from the surrounding hillsides, passed through silt traps, and water from the Tai lam Chung Reservoir should be the only discharges to the lake. Stormwater from

(63) ERM (1999). Environmental Impact Assessment of a 1,800MW Gas-Fired Power Station at Lamma Extension. Final Report.

any urban/developed areas should not be allowed to enter the lake as they may contain pollutants. Sewage effluent from the water recreation centre should be transported to the sewerage mains for conveyance to the Siu Ho Wan STW.

5.11.14 Any fuel for motorised vessels should be stored in bunded areas, of at least 110% capacity of the largest fuel storage container to prevent any accidental spills entering the lake. Servicing of any vessels should be undertaken at suitable facilities away from the artificial lake. In the unlikely event that fuel or other petroleum products do enter the lake a suitable clean-up plan should be implemented. The clean-up plan being devised by the operators of the water recreation centre and approved by EPD prior to the commencement of operations at the water sports centre.

5.11.15 The quality of the water in the lake is not predicted to be affected by the ingress of the contaminated groundwater because the lake will be lined with an impermeable liner. However, such liners may have a limited life span, beyond which the performance may deteriorate. In this case it is recommended that the liner be replaced once the manufacturer's specified life span is reached.

SEWERAGE SYSTEM

5.11.16 The flows to the Siu Ho Wan STW in 2005 at the time of the opening of the Theme Park have been found to be within the design capacity of the STW and as such no mitigation measures will be required in the form of increasing the capacity of the STW at this time. However, the assessment determined that in 2011 and later the STW would not have sufficient capacity to cater for the flows. This assessment was based on allowance for infiltration/inflow into the sewerage system as the system ages. There will be therefore be the necessity of increasing the capacity of the Siu Ho Wan STW prior to 2011. Such upgrade works would be the responsibility of the Drainage Services Department, the operators of the Siu Ho Wan STW.

5.11.17 The sewerage system to transport the sewage effluent from the Theme Park will undergo a detailed design to ensure that it is adequate to cater for the predicted flows. As part of this process it is recommended that rising mains be duplicated in order to minimise the risk of overflow under peak flows and to provide a means of facilitating routine maintenance.

5.11.18 In order to minimise the risk of failure at the two pumping stations serving the Theme Park development, at Yam O and at the north west boundary of the Theme Park the following measures should be implemented.

- dualling of rising mains;
- dualling of power supply; and
- provision of duty/stand by pumps.

5.11.19 The sewers following the boundary of the theme park are proposed to have on-line lift stations at approximately 300-600m intervals. The provision of these stations will reduce the depth of sewers and accordingly facilitate maintenance and eliminate potential problems associated with settlement in the deeper parts of the reclamation infill causing deformation to pipes.

5.11.20 In the event of failure of one or more of the on-line lift stations the consequence will be that the sewer upstream of the station will be surcharged and flows will be conveyed to the outfall to the pumping station at the north west corner of the theme park site. Provision of secondary power supply and standby pumps at each site will minimise the risk of failure. In addition, temporary storage tanks/wells should be provided where practical to further minimise the risk of the discharge of untreated sewage effluent. Furthermore, the proposed system will have adequate pipe gradients to ensure that cleansing velocities are achieved hence siltation is prevented.

5.11.21 All electrical and mechanical installations such as pumping stations should have telemetry systems to ensure that system failure is identified. This will facilitate early response to rectify any system failure. In order to reduce the potential of the failure of the pipes and joints due to differential settlement on the reclaimed land it is recommended that the following options for pipe construction be considered, which perform considerably better than clayware or concrete pipes.

- jointless pipes;
- HDPE pipes; and
- ductile iron pipes.

5.11.22 The provision of the above described measures will ensure that the risk for the discharge of untreated sewage to marine waters is minimised and as such it is predicted that no adverse impacts to water quality will occur as a result of the adequacy of the sewerage system.

ROAD AND RAIL LINKS

5.11.23 The following mitigation measures should be implemented to prevent adverse operational impacts to water quality from the road links.

- all road run-off should be collected and discharged via a stormwater drainage system;
- oil and grit interceptors should be incorporated into areas where spills are likely to remove any oil or grease and sediment before being diverted to the public stormwater system;
- the contents of oil and grit interceptors should be transferred to an appropriate disposal facility on a regular basis, the frequency of which would depend upon the amount of rainfall (ie more frequent removal during the wet season);
- silt traps or sedimentation tanks should be installed to remove suspended solids, which may contain heavy metals and PAHs, from run-off water and, in the same way as oil and grit interceptors, they should be regularly cleaned and maintained in good working condition.
- The following measures shall be incorporated into the operation of the PBRL to prevent adverse impacts to water quality.
- a surface water drainage system shall be provided to collect operational tunnel seepage. Where oils and lubricating fluids could be spilt, facilities shall be provided to remove the oil / grease before being pumped to the public stormwater drainage system. It is envisaged that the operational tunnel discharge and track runoff will pass through the oil and grit / silt interceptors / chambers to remove oil, grease and sediment, however, other suitable alternative methods may be used;
- sewage effluents shall be directed to the public foul sewerage system and/or on-site sewage treatment facility for treatment prior to discharge to the public foul sewerage system;
- the efficiency of silt traps and oil interceptors is dependent on regular cleaning and maintenance. These installations shall be regularly cleaned and maintained in good working condition; and this shall be incorporated into operational procedures;

- oily contents of the oil interceptors shall be collected for reuse, or transferred to a disposal facility;
- the design of the sanitary fitments and drainage works shall take into account the guidelines published in *Drainage Plans subject to Comment by the EPD, Practice Note for Professional Persons, Environmental Protection Department* (ProPECC PN 5/93); and
- a small waste water treatment plant (or other suitable alternative method) should be provided to remove detergents from the waste waters arising from the train washing facilities prior to discharging to the foul sewers.

5.12 RESIDUAL ENVIRONMENTAL IMPACTS

CONSTRUCTION

5.12.1 No residual environmental impacts were predicted to occur due to the Theme Park alone during the construction phase, provided that the mitigation measures, described in *Section 5.7* are implemented. The mitigation measures were specified in the form of constraints on the construction programme and as a series of 'best practice' methods of working.

5.12.2 However, the assessment of the cumulative impacts due to the construction of the Theme Park reclamations and other concurrent projects predicted that there would be an exceedance of the WQO for suspended sediment concentrations at the Ma Wan Fish Culture Zone. The implementation of the mitigation measures to the construction of the reclamations for the Theme Park resulted in the contribution of the construction of the reclamations for the Theme Park being minimised, less than 2 mg L^{-1}. It was noted that the predicted increases in suspended sediment concentrations were based on very much worst case assumptions and that the duration of the contribution of the Theme Park construction to the predicted elevated suspended sediment concentrations would be short. These assumptions were that the highest rates of working (ie highest predicted impacts) for each of the concurrent projects were assessed and that the impacts from each of the concurrent projects would occur at the same phase of the tidal cycle. The probability of these worst case impacts occurring is very small. In spite of the conservative nature of the assessment, it was determined that the predicted increase in suspended sediment concentrations at the Ma Wan Fish Culture Zone would not adversely affect the fish stocks. It is therefore concluded that the predicted exceedance of the WQO at the Ma Wan Fish Culture Zone is not an adverse impact and that there will thus be no residual impacts.

5.12.3 The monitoring programme for this project, coordinated with monitoring programmes for other concurrent project through an ENPO, will be able to determine whether adverse impacts are occurring at sensitive receivers and be able to attribute any exceedances to particular projects so that effective mitigation measures may be implemented. This will ensure that there are no exceedances of the relevant water quality standards and thus that there will be no residual impacts.

OPERATION

5.12.4 Modelling of the impacts to water quality from sewage effluent and stormwater discharges associated with the operation of the Theme Park predicted that no exceedances of the Water Quality Objectives would result from such discharges. For total inorganic nitrogen and *E. coli* there were predicted to be exceedances of the WQOs, which were predicted to occur without the discharges from the Theme Park. It was concluded that the discharges from the Theme Park were not causing adverse impacts to water quality as any breaches in the WQO could not be attributed to the Theme Park and that the Theme Park was not causing a deterioration in those areas where the WQOs were already breached. There are therefore not anticipated to be residual impacts to water quality as a result of discharges from the Theme Park.

5.12.5 Operational measures were defined to protect water quality within the artificial lake associated with the water sports centre and maintain its beneficial uses as a source of irrigation water, as a water sports recreation area and as an area of general amenity value. Measures were also defined to control accidental spills into the lake. The implementation of these measures will maintain water quality at acceptable levels and as such it is not anticipated that there will be any residual impacts from the operation of the artificial lake and water sports centre.

5.12.6 Provided that the sewerage system to convey the sewage effluents from the Theme Park to the Siu Ho Wan STW was designed to cater for the predicted flow rates then there would not be any adverse impacts to water quality in the vicinity of the Theme Park through the discharge of untreated sewage. It was determined that the Siu Ho Wan STW would not have sufficient capacity to treat the sewage effluent flows predicted to be generated beyond 2011 and as such there is a requirement to upgrade the STW. Provided adequate additional capacity is provided at the STW there are not predicted to be any residual impacts to water quality due to the inadequacy of the sewerage system and the Siu Ho Wan STW.

5.12.7 No residual environmental impacts to water quality were predicted to occur during the operation of the road and rail links, provided that the mitigation measures, described in *Section 5.12.3* are implemented. The mitigation measures were specified in the form of a series of measures to be included in the engineering design of the road and rail links and as operational constraints.

5.13 ENVIRONMENTAL MONITORING AND AUDIT

CONSTRUCTION PHASE

5.13.1 Water quality monitoring and auditing has been recommended for the construction phase. The specific monitoring requirements are detailed in *Annex N* of this EIA Report which comprises the stand-alone Project EM&A Manual.

OPERATION PHASE

5.13.2 Monitoring of marine water quality during the operations of the Theme Park is not recommended to be carried. It is, however, recommended that post construction monitoring of the quality of the water in the artificial lake be undertaken. The specific monitoring requirements are detailed in *Annex N* of this EIA Report which comprises the stand-alone Project EM&A Manual.

5.14 CONCLUSIONS

CONSTRUCTION

5.14.1 The construction phase assessment has considered the following aspects.

- the potential impacts to marine water quality from the construction of the reclamations at Penny's Bay and at Yam O, including cumulative impacts with other concurrent projects; and

- the potential impacts to marine water quality from land based construction works for the Theme Park and the associated infrastructure, including road and rail links.

Reclamation Construction

5.14.2 The potential impacts to marine water quality from the construction of the reclamations for the Theme Park at Penny's Bay was assessed by making reference to previous computer modelling studies of suspended sediment dispersion and water quality impacts of the construction of a reclamation at Penny's Bay for container terminals. The current proposed reclamation and measured sediment quality were compared to those assumed for the previous reclamation to calculate the water quality impacts due to the Theme Park reclamation from those predicted in the previous modelling. It was determined that there would be no adverse impacts to water quality from the construction of the reclamation at Penny's Bay provided that a number of mitigation measures were implemented.

5.14.3 The impacts from the construction of the Yam O reclamation were assessed by calculating the increases in suspended sediment concentrations due to the dredging works using a desk top calculation method and then calculating the associated water quality impacts using measured sediment quality. It was predicted that there would be no adverse impacts to water quality provided that suitable mitigation measures were implemented.

5.14.4 The assessment of cumulative impacts was made by taking the results of previous computer modelling of increases in suspended sediment concentrations at sensitive receivers for potentially concurrent projects. The results of the previous computational modelling were summed with the predicted increases in suspended sediment concentrations from the Theme Park reclamations at the sensitive receivers. It was determined that there would be an exceedance of the WQO for suspended sediment at the Ma Wan Fish Culture Zone. Through mitigation of the construction of the Theme Park reclamation the contribution of the Theme Park reclamation construction to the total suspended sediment concentration could be minimised to contribute only a small amount to the total predicted increase in concentrations. It was noted that the cumulative assessment was based on a very conservative assessment methodology, which meant that the likelihood of the predicted cumulative impacts occurring will be very small and that the duration of the contribution of the Theme Park reclamation construction to the elevated suspended sediment concentrations would be small. Despite the conservative nature of the assessment it was determined that the predicted increases in suspended sediment concentrations would not result in adverse effects on the fish stocks (see *Section 9*). It was therefore concluded that the predicted exceedance of the WQO could not be considered an adverse impact. In addition, the monitoring and audit programme would ensure that no adverse impacts would occur by triggering appropriate mitigation measures for the particular projects identified as contributing to any detected impacts. Therefore, there are not predicted to be any adverse impacts to water quality due to cumulative impacts.

5.14.5 Mitigation measures for the construction of the Theme Park reclamations were specified in terms of operational constraints (eg limiting the rate of working, construction sequence for the reclamation and methods of construction) and 'best practice' working methods. The implementation of these measures would prevent adverse impacts to water quality.

5.14.6 It was recommended that Environmental Monitoring and Audit (EM&A) programme be carried out during the construction of the Theme Park reclamations at Penny's Bay and Yam O to ensure that no adverse impacts to water quality would occur and to trigger further mitigation measures should adverse impacts be detected. The EM&A programme would also serve to identify whether the construction of the Theme Park reclamations was responsible for any adverse impacts or whether these could be attributed to other concurrent projects.

Land Based Construction Activities

5.14.7 It was determined that the potential for adverse impacts to water quality from land based construction activities for the Theme Park and associated infrastructure would primarily be from contaminated surface run-off and from sewage effluent generated by the construction workforce. A number of mitigation measures were specified to reduce the potential adverse impacts to acceptable levels.

OPERATION

5.14.8 The operation phase assessment has considered the following aspects.

- the potential impacts to hydrodynamics from the Theme Park reclamations and to marine water quality from sewage effluent and stormwater discharges from the Theme Park and surrounding areas;
- the protection of water quality in the artificial lake so that its beneficial uses as a recreation are for water sports, as a source of irrigation water for the Theme Park and as an area of general amenity value may be maintained;
- the adequacy of the sewerage system and of the Siu Ho Wan Sewage Treatment Works so that adverse impacts to water quality due to the discharge of untreated sewage effluent to marine waters may be prevented; and
- the potential impacts to marine water quality from the operation of the road and rail links for the Theme Park.

Hydrodynamics and Water Quality

5.14.9 The potential impacts to hydrodynamics from the Theme Park reclamations were assessed using computational modelling. The modelling predicted that the Theme Park reclamations would have only minimal effects on tidal current speeds and directions. It was predicted that there would be a reduction in the flushing of the areas to the south west of the reclamations, Sze Pak Wan and Discovery Bay, which would have the potential to cause adverse water quality impacts. These potential impacts are discussed in the following paragraph.

5.14.10The potential impacts to water quality from the discharge of sewage effluent and stormwater were using computational modelling. The sewage effluent flows from the Theme Park will be conveyed to the Siu Ho Wan Sewage Treatment Works, while the stormwater will be discharged to the south and east of the Theme Park. The increased treated effluent flows from the Siu Ho Wan STW due to the load from the Theme Park and the stormwater discharges were included in the water quality modelling. The water quality modelling predicted that there would be no breaches of the Water Quality Objectives due to the sewage effluent and stormwater discharges from the Theme Park. It was also predicted that the water quality in the areas to the south west of the Theme Park would be acceptable. It was therefore concluded that there would be no adverse impacts to water quality due to sewage effluent and stormwater discharges from the Theme Park and as such no specific mitigation measures would be required. It was recommended that a performance verification study to monitor the performance of the Siu Ho Wan STW be carried out following the completion of the Theme Park to determine whether the STW was performing to the specified standards.

5.14.11 During the operation of the Theme Park there would also be the potential for the discharge of toxic substances comprising residual chlorine, pesticides and biocides. Suitable operational constraints and mitigation measures were devised to prevent adverse impacts to water quality from the discharge of these substances.

Artificial Lake

5.14.12 Appropriate standards were defined for the water quality within the artificial lake with reference to its beneficial uses. The quality of the water to be used to fill the lake was assessed to determine whether it would be suitable to maintain water quality. Suitable sources of water with acceptable quality were identified. Operational constraints and mitigation measures were also devised and with the implementation of these measures it was determined that water quality within the artificial lake could be maintained to an acceptable level.

Adequacy of the Sewerage System

5.14.13 The adequacy of the sewerage system was assessed with regard to the required capacity of the sewers to convey sewage effluent from the Theme Park to the Siu Ho Wan STW and of the capacity of the Siu Ho Wan STW to cater for the increased flows due to the operation of the Theme Park. It was determined that the sewers could be designed to have adequate capacity and that the capacity of the Siu Ho Wan STW should be increased. This would necessitate upgrading works at the STW, which would be the responsibility of the Drainage Services Department. Suitable measures were devised to minimise the risk of emergency discharge from the sewers and to reduce the duration of any such events. It was assessed that there would therefore be no adverse impacts to water quality due to the sewerage system not being able to cope with the sewage effluent flows from the Theme Park.

Road and Rail Links

5.14.14 The road and rail links to the Theme Park would have the potential to cause adverse impacts to water quality through discharges from these infrastructure developments, primarily through surface run-off. Suitable mitigation measures were devised to minimise these impacts and hence prevent adverse impacts from occurring. Operational constraints were placed on aspects of the rail link to prevent adverse impacts. It was therefore assessed that there would be no adverse impacts to water quality from the operation of the road and rail links to the Theme Park.

5.15 IMPACT SUMMARY

5.15.1 Water quality impacts due to construction and operation of the proposed International Theme Park at Penny's Bay and Its Associated Infrastructure have been summarised in *Table 5.15a* as follows.

Table 5.15a - Impact Summary Table

Issue	Construction Impact	Operational Impact
Assessment Points	• Impacts to water quality from dredging and filling for the Penny's Bay and Yam O reclamation, including the cumulative impacts with potentially concurrent projects; and • Impacts to water quality from land based construction works for the Theme Park and the associated infrastructure, including road and rail links.	• Impacts to hydrodynamics from the Theme Park reclamations and the impacts to marine water quality due to sewage effluent and stormwater discharges; • The protection of water quality in the artificial lake so that its beneficial uses may be maintained; • The adequacy of the sewerage system and of the Siu Ho Wan STW so cater for the sewage effluents from the Theme Park; and • The impacts to marine water quality from the operation of the road and rail links.
Relevant Criteria	• Water Pollution Control Ordinance; • Technical Memorandum for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters; • Environmental Impact Assessment Ordinance (Cap. 499 S16), Technical Memorandum on Environmental Impact Assessment Process, Annexes 6 and 14; and • Practice Note for Professional Persons, Construction Site Drainage (ProPECC PN 1 /94).	• Water Pollution Control Ordinance; • Technical Memorandum for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters; • Environmental Impact Assessment Ordinance (Cap. 499 S16), Technical Memorandum on Environmental Impact Assessment Process, Annexes 6 and 14; and • Drainage Services Department Sewerage Manual.
Potential Impacts	• No adverse impacts to water quality from the construction of the Theme Park reclamations alone; • It was predicted that there would an exceedance of the WQO at the Ma Wan Fish Culture Zone due to cumulative impacts, but that the Theme Park would contribute minimally to the predicted adverse impacts following the implementation of mitigation measures and that the contribution would be of short duration; • It was determined that the predicted exceedance of the WQO would be not cause an adverse impact to the fish stocks (see *Section 9*); and • No adverse impacts to water quality during land based construction activities, provided that 'best practice' measures implemented.	• No adverse impacts to hydrodynamics and water quality were predicted due to the reclamations and the discharge of sewage effluents and stormwater; • It was determined that the sewerage system to convey sewage effluents from the Theme Park to the Siu Ho Wan STW could be designed to have adequate capacity; • It was predicted that the Siu Ho WAN STW would be able to cater for the sewage effluent flows from the Theme Park in 2005 (Theme Park opening) but by 2012 the Siu Ho Wan STW would not have sufficient capacity; • No adverse impacts to water quality from the operation of the road and rail links were predicted, provided certain design features were incorporated.

Issue	Construction Impact	Operational Impact
Mitigation Measures	• Operational constraints were specified for the construction of the reclamations, in terms of rates of working, methods of construction and sequence of construction; • Mitigation measures would serve to minimise the Theme Park reclamation construction contribution to the predicted cumulative impacts, as discussed above; • In addition, 'best practice' working methods were specified for reclamation construction; and • For the land based construction activities measures were specified to minimise the potential for contaminated surface run-off entering marine waters and to prevent the discharge of untreated sewage effluent.	• No mitigation measures were required due to the potential impacts to water quality from the changes to hydrodynamics and the discharges of stormwater and sewage effluent; • Operational constraints to control the quality of the water to fill the lake were devised; • Further mitigation measures included the use of a watertight liner for the lake and preventing accidental spills to the lake; • The capacity of the Siu Ho Wan STW should be increased prior to 2012 to prevent overloading; • Measures were devised to minimise the risk of emergency discharges; and • Measures were devised to mitigate the potential impacts due to surface run-off from the road and rail links.
Residual Impacts	Cumulative impacts, based on a conservative assessment methodology were predicted to exceed the WQO at the Ma Wan Fish Culture Zone but would not be considered to be an adverse impact (see *Section 9*).	No residual impacts to occur were predicted to occur provided that the recommended mitigation measures were implemented.
Environmental Acceptability	Acceptable.	Acceptable.

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